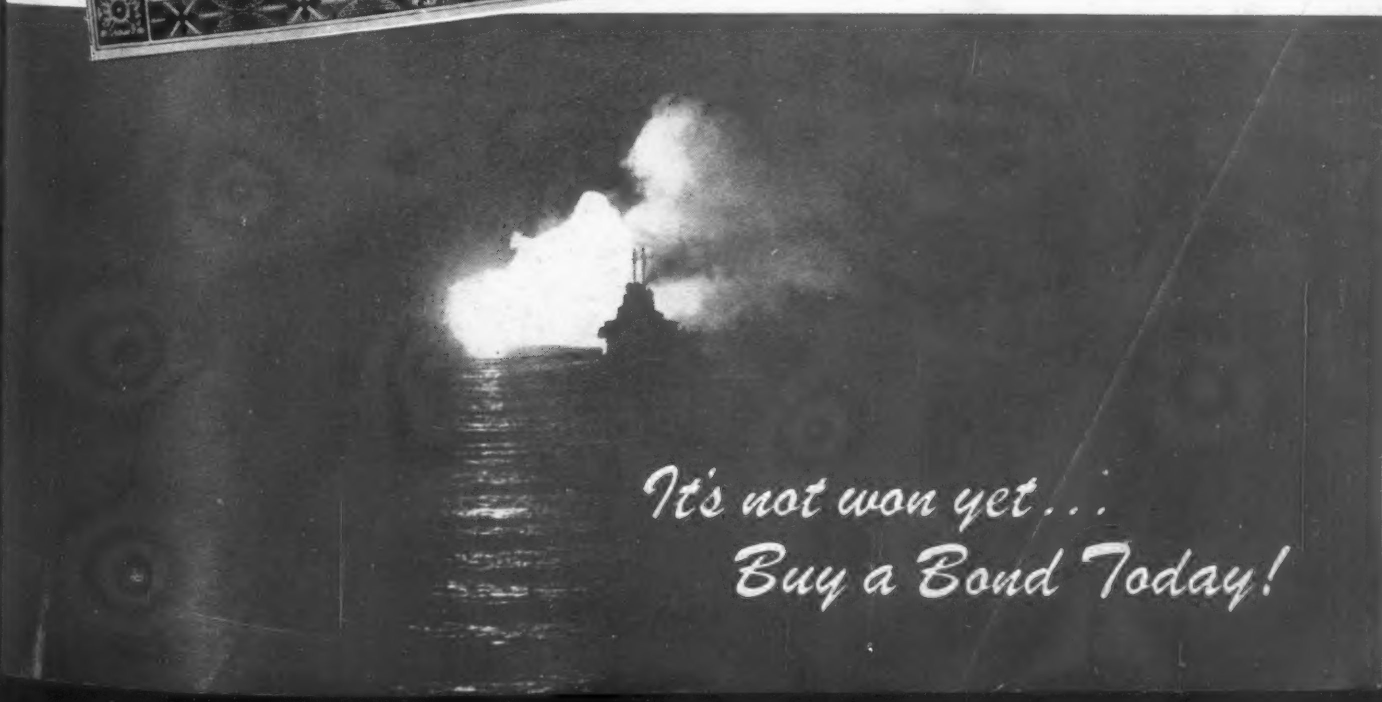
MACHINE DESIGN

June 1944




WHAT TO DO WITH MOTOR CONTROL
IN MOTORIZED MACHINE DESIGN
The problem of what to do with the motor control in a motorized machine is no problem at all when you use UNITROL. The motor control then becomes virtually a part of the machine housing, and you locate it where it is most convenient for the operator. In addition, a lot of other problems answer themselves. You gain the desired streamlined appearance, free from bulky, unsightly units outside the machine; you eliminate mounting, assembling and wiring difficulties commonly encountered with built-in control; you save weight, material, machining time and costs. And UNITROL is so flexible it can accommodate *all* the control elements for any multi-motored machine. UNITROL definitely deserves a place on your post-war machine design program. Make a memo to write for the big UNITROL book *today* . . . an important step in getting ready for *tomorrow*. . . . CUTLER-HAMMER, Inc., 1310 St. Paul Ave., Milwaukee 1, Wisconsin. Associate: Canadian Cutler-Hammer, Ltd., Toronto, Ont.
UNITROL is primarily a means of mounting skeleton starters. Here is shown the basic UNITROL mounting frame, which simplifies machine design and construction.
Here a skeleton starter is mounted in place in UNITROL frame. Door may be plain or pierced for pushbuttons, on-off switch, etc.
Built-in control through the simple expedient of UNITROL. A cavity is cut in the machine housing, four screw-holes tapped and UNITROL is simply screwed into place.
You can do all sorts of things with UNITROL. Here 6 control elements are mounted in one frame, door arranged for external pushbutton operation; the entire unit is ready for quick, easy installation.
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C-H

MACHINE DESIGN

THE PROFESSIONAL JOURNAL OF CHIEF ENGINEERS AND DESIGNERS

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JUNE, 1944 Volume 16—Number 6

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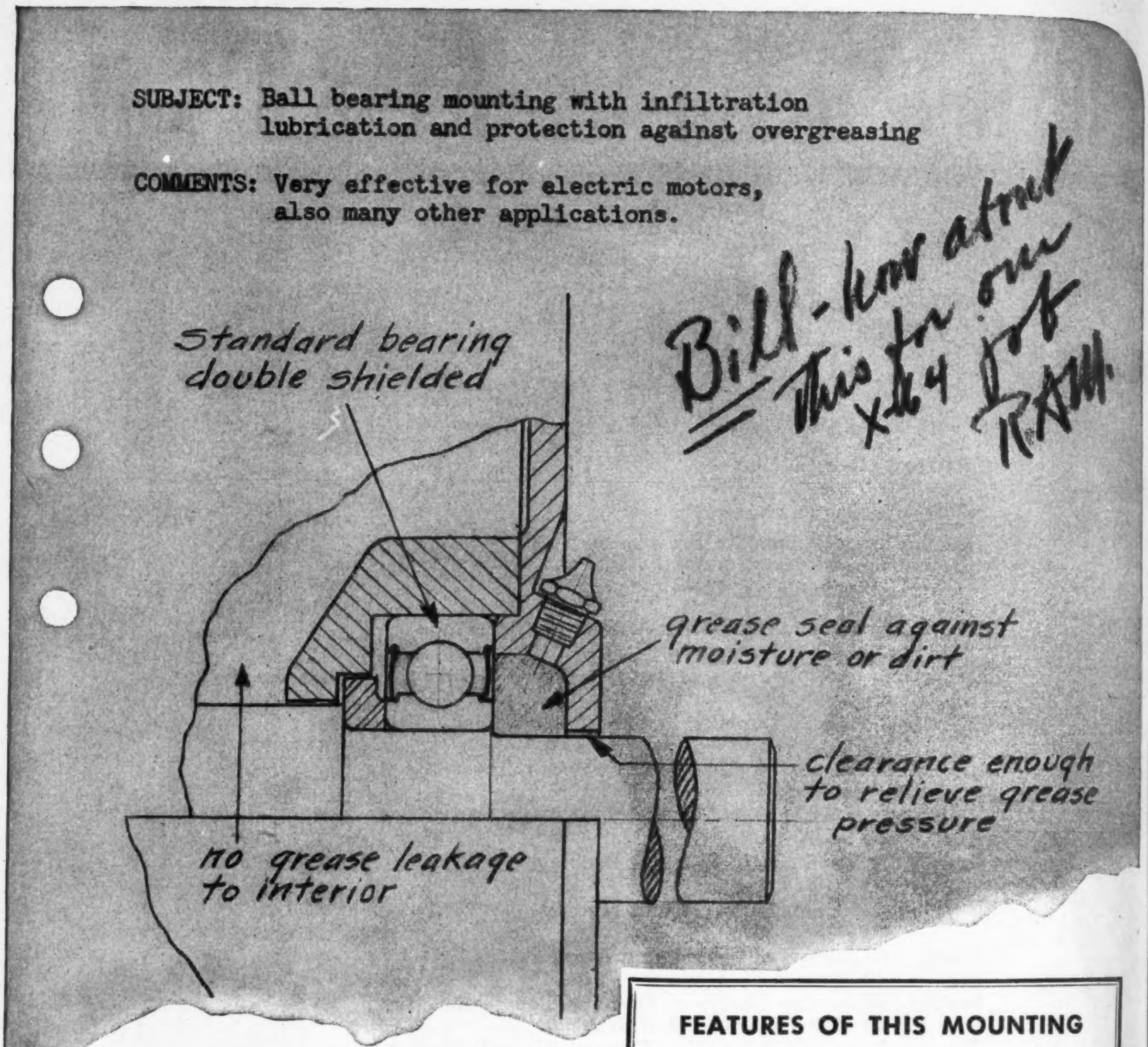

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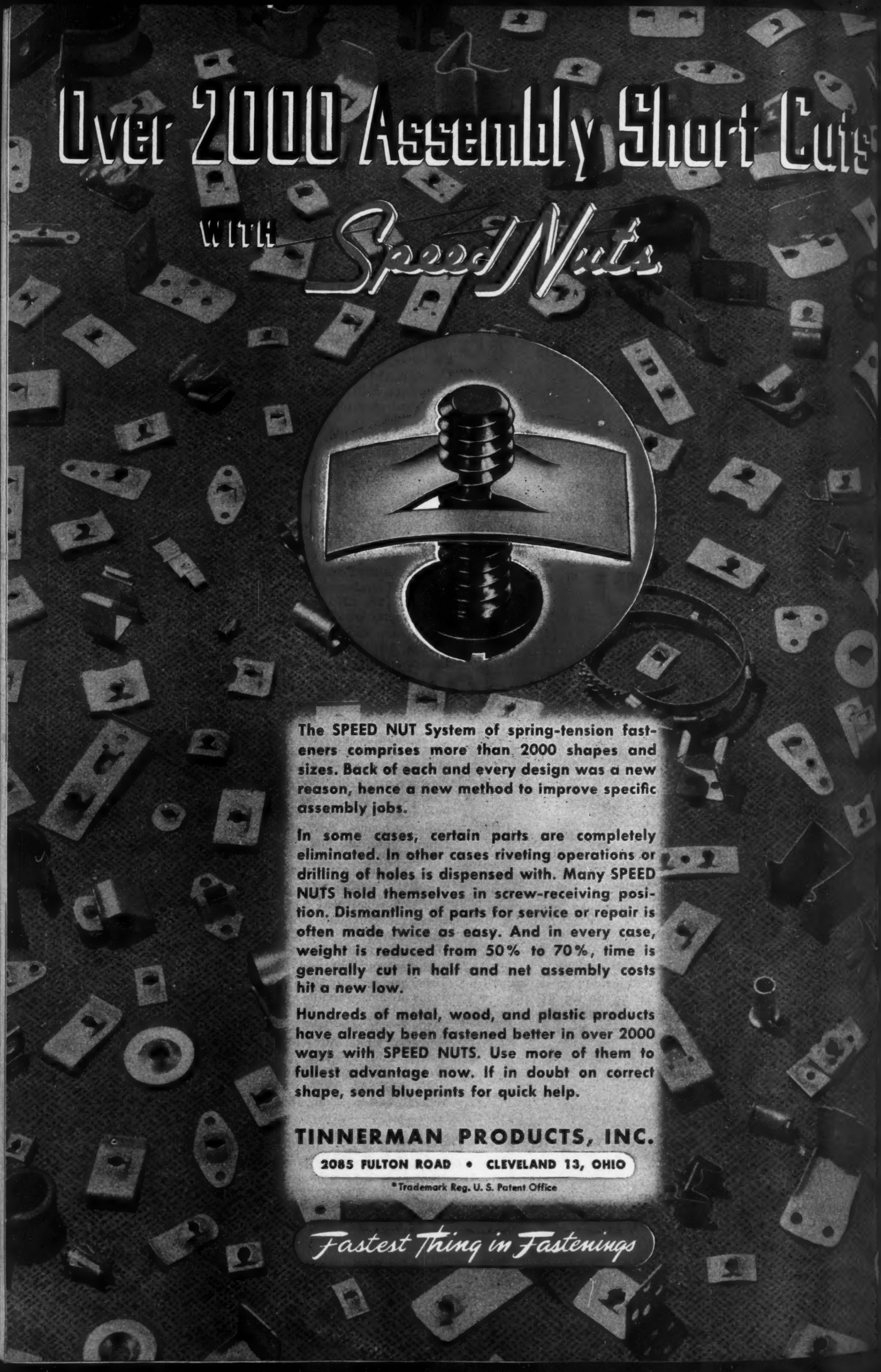
Itemized Index

Classified for Convenience when Studying Specific Design Problems

MACHINE DESIGN is indexed in Industrial Arts Index and Engineering Index Service, both available in libraries generally.



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This issue at a glance

Women Can Be and Are Being Trained . . . .

. . . . to do excellent work in the drafting room. Right now they're pinch hitting in many engineering departments for draftsmen who are in the armed forces. In the lead article of this issue—Page 95—a proved system for training the draftswoman is discussed.

Enveloping Worm Drives Are Used Extensively . . . .

. . . . on battleship gun turrets, fire-control computers and variable-pitch propellers. Also known as hour-glass, spheroid and globoid worm drives, they offer maximum strength, minimum backlash and have modest space requirements. A timely presentation giving design and manufacturing considerations will be found on Page 135.

Great Strides Have Been Made . . . .

. . . . during recent years in the application of machine hydraulics. Automatic, interlocking systems are dependent largely on the proper utilization of standard and special valves. For the "whys" and "wherefores" of such valves in representative modern systems, turn to Page 117.

Modern Mass Production Methods . . . .

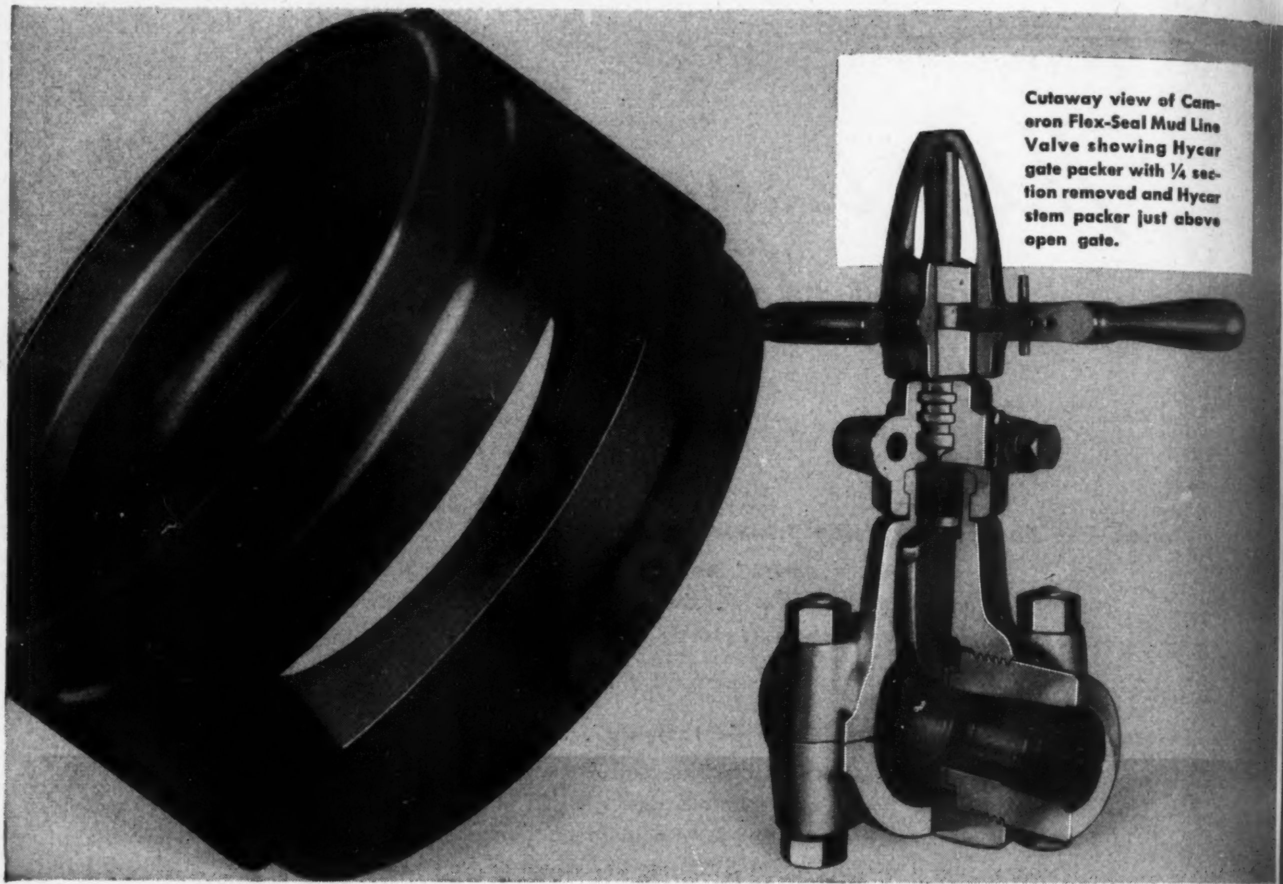
. . . . demand continuous improvement in techniques of drafting. Drawings must give information quickly, with minimum of study. Thus the trend is toward pictorial types. Shadowgraph technique is easy to master—doesn't require an artist. Page 129.

Electric Motors Don't Live Long . . . .

. . . . when they run a temperature. How many reversals will a motor tolerate without overheating? To what extent is performance affected by motor type? And what limitations do enclosures impose? Get the story on this important subject from G. B. Carson's "fact-full" article. It's on Page 103.

Hydraulic Variable-Speed Transmissions . . . .

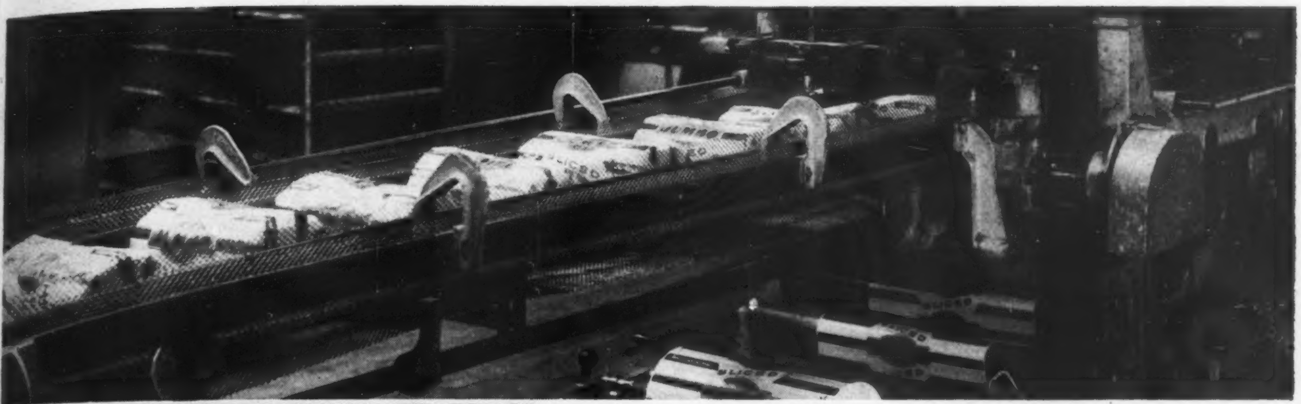
. . . . are of two basic types—hydrokinetic and hydraulic displacement. Both have their place. But where and how to use them can be puzzling. Specification and design information pertaining to currently available units is presented commencing on Page 107.

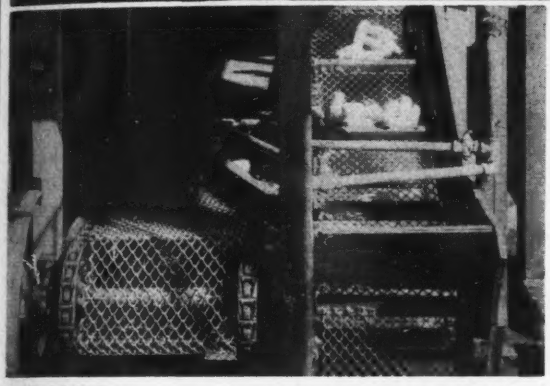


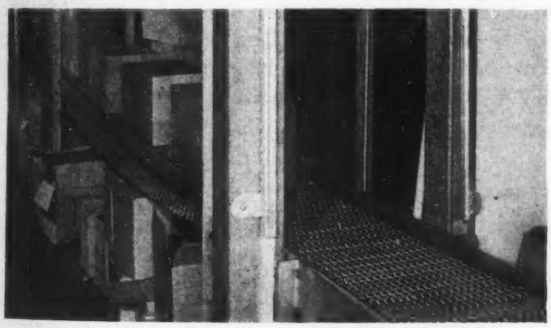
Cutaway view of Cameron Flex-Seal Mud Line Valve showing Hycar gate packer with ¼ section removed and Hycar stem packer just above open gate.

Closeup of Hycar Gate Packer.

Photographs courtesy Cameron Iron Works, Houston, Tex.







Cambridge
CONVEYOR
BELTS

Topics

"white gas" which must be especially procured for the purpose. Under test the unit operated more satisfactorily on regular motor fuel than original designs do on white gas. The improvement involves controlling the heat on the generator in which the gasoline is vaporized. The generator is sufficiently far from the burner to prevent the heat from breaking down the gasoline and clogging the passages yet close enough to assure complete vaporization.

FILAMENTS almost invisible are being produced with the aid of a crossbow device to stretch quartz to .00003-inch threads. The high initial burst of speed obtained from the cross-bow "spins out" the quartz while it is in a hot, fluid state and before it has a chance to cool and harden. Finer still, platinum filaments which measure .000013-inch are being manufactured by drawing silver wire with a platinum core to an overall diameter of .002-inch and placing a few drops of nitric acid on the required short length. Action of the acid dissolves the silver, leaving the platinum thread.

JAPANESE conversion of textile spinning machines into lathes and other machine tools, according to a Domei dispatch, has been "successfully achieved by experts of the Ohmi Aircraft Co. in central Japan after months of experimenting." These experts found "practically all of the spinning looms, with minor changes, can be used in construction of machine tools." The Ohmi company's plants were said to be using frames, rails, gears, roller and ball bearings, nuts, bolts, springs, shaft bearings and other parts of spindles in the conversion.

BRONZE-FACED pistons for the landing struts on P 47 fighters are being produced by flame spraying bronze alloy on the steel bearing surface. Comparatively light steel blanks, designed by the Neo Mold Company, are sprayed to a thickness of .045-inch on the rough machined bearing surface and then given the required high finish with oil grooves. The process uses only three and one-half pounds of bronze instead of seven formerly required, resulting in a stronger and somewhat lighter piston. Also, the sprayed bronze, being porous, has self-lubricating properties.

CONVERSION UNITS for gasoline burners have been developed by the Quartermaster Corps to permit the use of all types of gasoline instead of only

ENGINEERING DATA available up to the present on plastics are not in perfect agreement. Consequently, authoritative sources have agreed to furnish comparable values to be used in a classification table being prepared by the Society of the Plastics Industry. The simplicity of the proposed presentation will be of great help to designers.

COLLEGE PROGRAM to train girl high school graduates as engineering drafting aides has been established at Purdue university. The program is set up to train 70 girls in a 23-week intensive course. In connection with women in engineering work the leading article in this issue discusses the program employed at Sperry Gyroscope.

MOTORCYCLE, light enough to accompany paratroopers as they drop from the skies, has been developed with steel-cable reinforced V-belt between the power unit and rear wheel. Weighing 150 pounds, this Simplex motorcycle is the only motorized vehicle in the U. S. Army which can be dropped from an airplane with one standard 24-foot canopy chute.

HARD SKIN of armour plate was pierced in a recent demonstration to show how drilling may be facilitated by the use of a Thomas tap extractor, a device developed for removing broken taps. The initial operation was performed by this device, followed by standard drilling of the plate. Principle of the extractor is disintegration of the metal, utilizing an electronic unit and a hollow electrode through which a coolant flows.

Training Draftswomen For Emergency Work

By W. J. Kowal and D. J. Paolucci
Sperry Gyroscope Co. Inc.

DEMANDS of the armed services for more and more manpower drained many engineering plants throughout the country of highly skilled personnel early in the war. The drafting room felt the pinch as much as did other divisions of engineering departments and, with practically no new male personnel available, it became imperative to call upon women to fill the breach.

Employment of women in the drafting room is somewhat of an innovation, there having been comparatively few draftswomen in the past. Only a limited number of women have set their sights on careers in engineering so that at the outset of hostilities our colleges were not

Fig. 1—Mr. Kowal (seated) and Mr. Paolucci analyze a layout for a student in advanced group preparatory to detailing

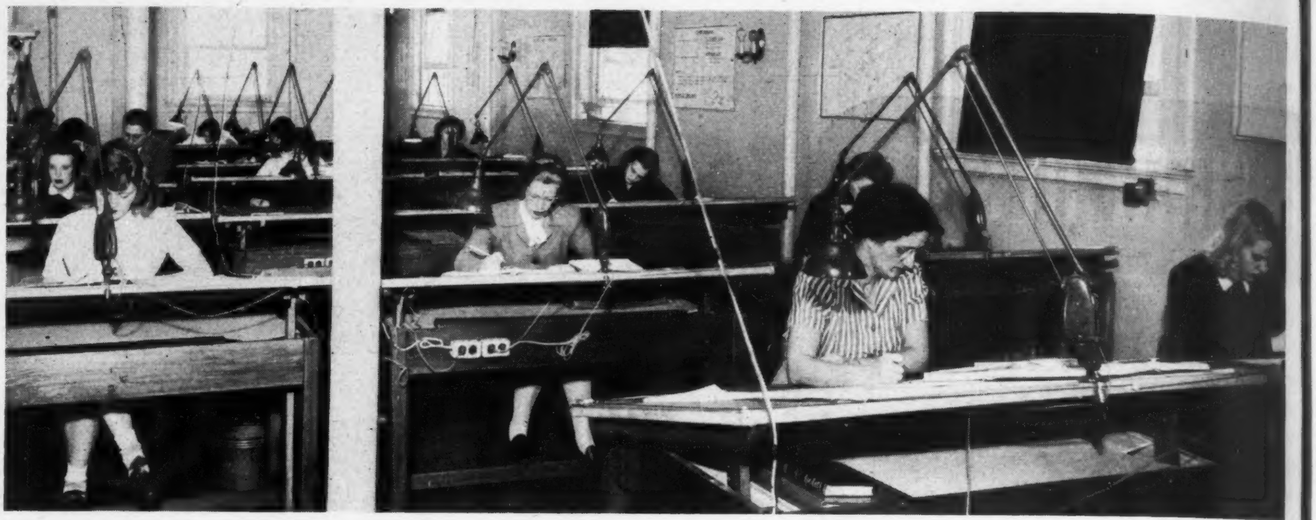


Fig. 2—Trainees of elementary group practising drawing in company school. Equipment used throughout training program is identical to that used in regular drafting room

in a position to supply industry with the number of schooled draftswomen required. Fortunately, however, there have been a goodly number of college women who have majored in mathematics and also have taken an active interest in physics. This background knowledge has been a definite attribute and has made women possessing it particularly adaptable to drafting work.

Like most engineering organizations, Sperry methods of making and handling drawings are based on standards drawn up over a period of years, and these standards have proved satisfactory in meeting efficiently the specific needs of our organization. Thus, while schools sponsored by both government and private agencies have been organized and offer worthwhile training courses in drafting to women, we have found that our needs are filled best by women trained in our own school. It is hoped that the following discussion, dealing with the training procedure we have employed, will, at least to some extent, help other engineering organizations in working up satisfactory training programs.

No Basis for Skepticism

There has been some skepticism as to the adaptability of women in the field of drafting. It is our considered opinion that there is no basis for such skepticism providing a reasonable amount of care is exercised in selecting the women to be trained. Naturally, no short-term program is going to make an experienced designer or engineer of a college graduate, man or woman. But, where the need is for good detailers, capable of working directly from designers' layouts or of making assembly drawings from details, women, after a short, concentrated training course, are proving especially adaptable.

At the Sperry school some fifty women starting as novices in the field of drafting have attained the more dignified classification of "Women's Emergency Engineering Design Service" under the special war training program conducted by the Design Services Department of the Research Laboratories. That they have earned their new title and justified the faith placed in them is evidenced by the type and caliber of their work.

Extension of the company's research laboratories in 1942 produced a critical situation in drafting personnel. Realizing that the situation was urgent and could not be handled adequately through the usual channel of employing experienced help, Charles B. Shepherd, superintendent of the Design Services and Training Departments, took steps to meet this shortage problem. It was then decided to organize the training program for women. A careful analytical study of the results desired was made and definite objectives outlined. To meet these objectives in an effective manner, a period of intensive training covering six months was decided upon.

An extremely important consideration of those responsible for the organization of the training program was the type of trainee to be admitted. After careful study the following prerequisites were set up:

1. Educational Background
   Preferably a college education with a major in mathematics and a minor in physics, or at least two years of college with studies in mathematics and physics
2. Experience
   Actual drafting experience in industry or completion of drafting courses offered in school
3. Age
   Between 22 and 35 years
4. Accessibility to Work
   Commuting time must not be excessive
5. Health
   (a) Good eyesight
   (b) Good general physical condition.

After more than a year's experience it has been found that the greatest emphasis should be placed on the educational background of the learner. However, as is usually the case when the problem of supply and demand is complicated by war conditions, exceptions had to be made in the requirements for promising applicants and some high school graduates with a good background in mathematics and physics were accepted.

The second requirement also had many exceptions. It proved almost impossible to find women with drafting experience and only a few had obtained brief training such as that offered in government-sponsored war training courses. Hence the requirement of previous drafting experience had to be considered lightly.

Requirement 3, however, offered no difficulties whatsoever. While promising applicants outside the age limits were accepted, the majority of those selected were in the lower part of the designated age range. As for the fourth requirement, it has been found that accessibility to the place of employment is an important factor in the production of good work. Traveling 2½ to 3 hours to and from work is not conducive to best results.

In part (a) of the health requirement, the necessity for good eyesight in the drafting room is of course obvious. Although the need for a good general physical condition is probably no more than that for workers in many other departments, it is important to ascertain this before an applicant is accepted. Much more time and money is spent on a trainee in this program than for many other departments handling war work and it is vital that these should not be wasted on one who may drop out because some physical defect develops.

In connection with this there is an important item which cannot be listed as an entrance requirement and yet is connected closely with these prerequisites. This critical item, to be considered during the training period, is steady attendance. Stressing numbers 4 and 5 of the prerequisites has eliminated much of this as a problem. However, some trainees have been dropped because of an erratic attendance record. It is felt that such a record is an indication of future habits and, with absenteeism as it is, this is considered a matter of major importance.

The course itself was based upon the results of a careful survey of the work done in the drafting room to which these women were to be assigned upon completion of their training period. Training is divided into two phases, basic and advanced. These are closely related. In the basic course the trainees learn the language of engineering drawing and Sperry engineering practice as well as the drafting techniques that will be required. In the advanced phase they put this knowledge into practice in detailing actual design layouts supplied by the design services department at the research laboratories.

Length of time devoted to basic training is approximately fifteen weeks, six days per week, eight hours per day. A refresher course in algebra, geometry and trigonometry is given also in conjunction with the basic training. Two sessions per week of two hours each for twelve weeks are devoted to mathematics and a similar amount of time to mathematics assignments. Thus, approximately one-sixth of the time devoted to basic training is given over to mathematics. Tests in each phase of mathematics are given to the trainees as the program progresses.

To meet the problem of a general lack of shop experience and knowledge of machine tools, as well as understanding of materials and machining procedures, supervised trips are arranged through one of the production plants of the

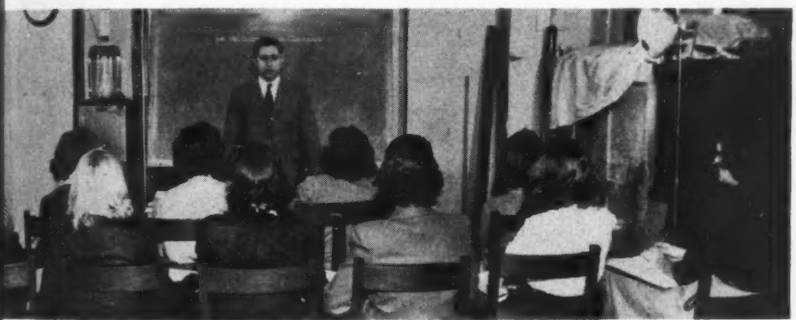


Fig. 3—Class lectures are an important part of the training program. Here, prior to a group tour through pattern and foundry shops, the instructor explains the various processes involved in the production of castings

Fig. 4—Individual instruction is required to insure thorough understanding of what is taught in group sessions. Constructive criticism is offered on dimensioning, method of showing views, etc.

company. Visits through the pattern shop and core making and foundry departments are made preparatory to visiting the machining areas. Many of the castings observed in the foundry are seen as the various machining operations are being performed. Here also the trainee becomes acquainted with the various shop machines such as lathes, milling machines, drill presses, automatic screw machines, grinders, etc., and the operations which she will have to note on drawings. To complete the picture an inspection is made of the assembly area, where parts noted in the machining and fabricating areas are observed in the final stages of assembly and testing.

Another teaching device used is the motion picture. Movies on machine operation, testing equipment and shop procedures are shown once per week. These inspection trips and films are, of course, correlated with lectures and drawing problems.

Advanced training provides the trainees with the opportunity of applying what has been learned to actual drafting room problems. Layouts are furnished by the design services department and vary from simple parts to complex assemblies. From these layouts the trainees are taught to do detailing of every manufactured article to be used, conforming to the company's standards—a necessity in Sperry drafting rooms. The next step is learning to make subassembly drawings and, finally, the assembly drawing from the details. The fact that the trainee's drawings at this stage are accepted by those in charge of the drafting room builds up the individual's confidence in her work—an important item in the training program. This does a great deal toward eliminating the need for "special" supervision when she goes on the job. Incidentally, this advanced period of training, while set at eleven weeks, may cover more or less time depending on the student herself. Capable trainees have completed it in six weeks and have been transferred to productive work immediately. The length of the training period has varied with individual trainees and has ranged from four to six months.

That women can do good quality work and can make neat drawings has been definitely proved by these trainees. Since quality and quantity are closely related factors in productive work the emphasis is laid first upon quality. It has been found that added experience molds the trainee into a draftswoman capable of both. Experience has shown that emphasis must be placed on the study of detail and the greatest attention given to the reason for each step. Therein seems to lie a real difference in the training of men and women for drafting. Women respond well to constructive criticism. Supervision during this period of training is a major item and involves a great deal of individual attention as the work progresses.

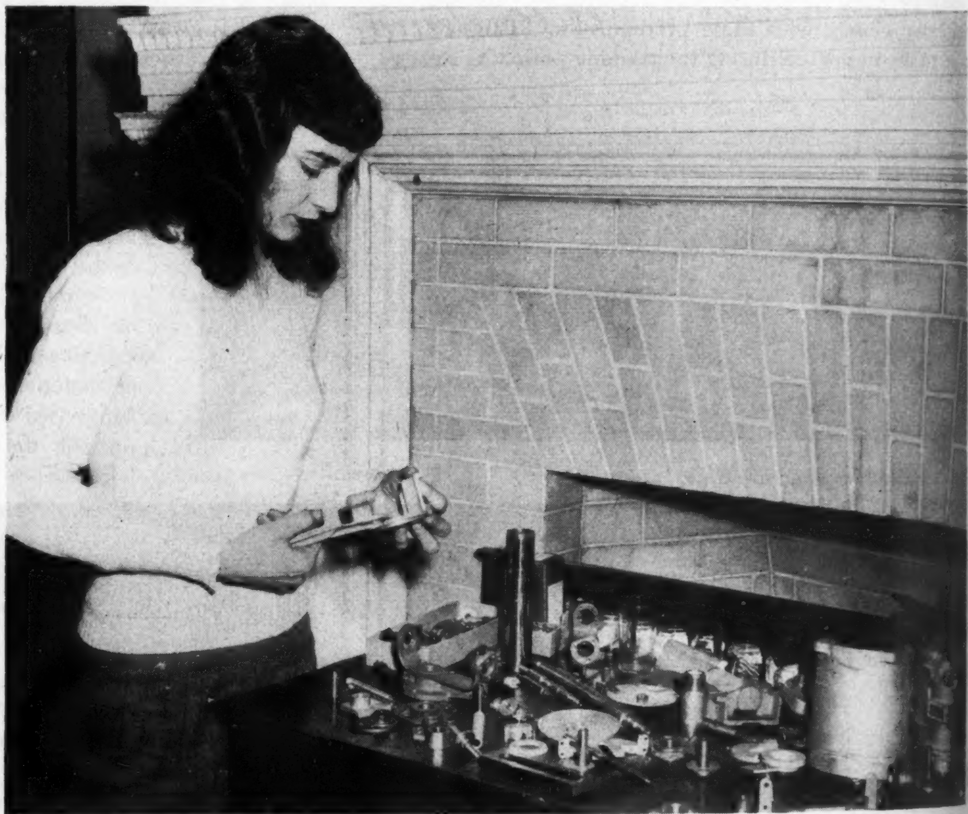


Fig. 5 — Student familiarizing herself with a variety of typical machine parts which serve as an ideal visual aid

Trainees possessing full requirements have, on an average, completed the training in four and one-half months, while those possessing minimum requirements usually need the maximum period of six months. While this does not detract from the capability of the latter, it does give a clear indication of the time required before some of the women can be placed on productive work.

When the first trainees became full-fledged members of the W.E.E.D.S. and started upon productive work it was found that no more "special" supervision was needed for them than for men. In every way they have adapted themselves to conditions in the drafting room and have assumed the responsibility for their share of the work. There is no reason to doubt the ability of women to do high quality drafting work when they have had sufficient intensive training.

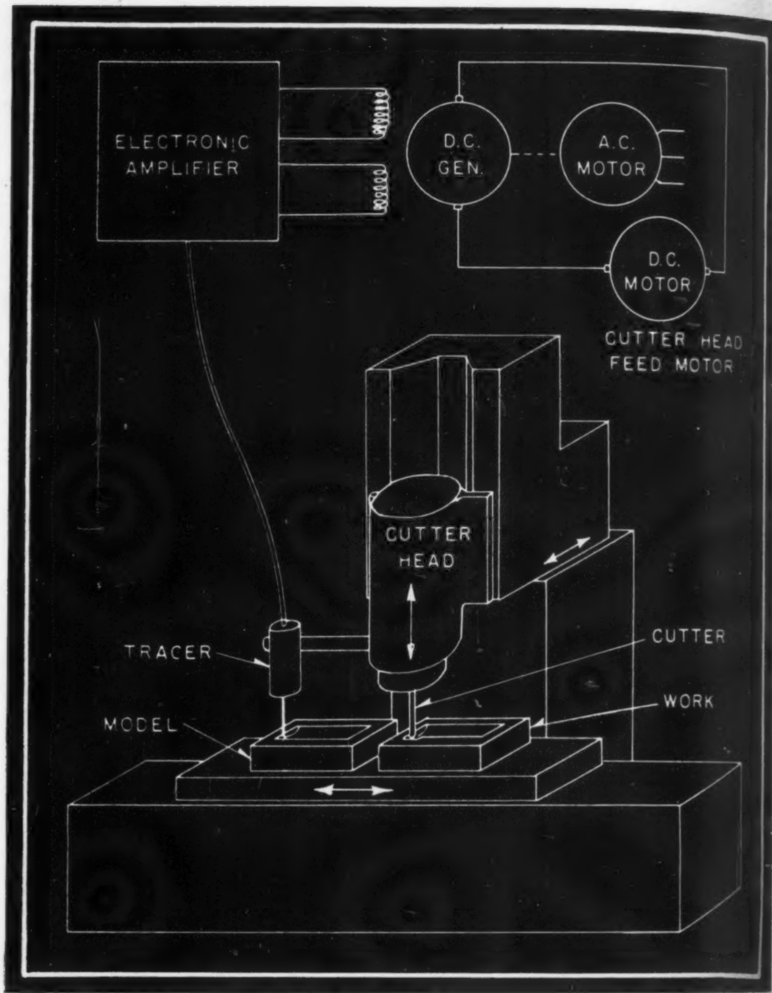
Scanning the Field for Ideas

Glass-reinforced plastics, having proved successful for many applications, have been developed for structural members and applied to the Army basic training plane illustrated, having the fuselage, side panels and tail cone of high-strength laminate. Consisting of a balsa wood core between an inner and outer skin of plastic reinforced with fibrous glass cloth, the material is 50 per cent stronger than metal fuselage and 80 per cent stronger than plywood construction on a strength-weight basis. Under gunfire the laminate does not flower and its low density does not detonate high-explosive projectiles.

The airplane sections were fabricated at Wright Field, utilizing heat-treated Fiberglas cloth and short, fine fibers known as Fiberglas flock. The resins were Plaskon 900, Laminac P-4122, MR-1A, Monsanto 38691, CR-39, CR-39Bd and CR-149. Each of the various combinations of glass and resin was fabricated into 1/4 and 1/2-inch thick laminated sheets. Molding of shapes is accomplished in forms such as shown at left by placing a rubber blanket over the impregnated plies and applying a vacuum to the underside of the mold. In this way atmospheric pressure replaces high-pressure autoclaves.

Tensile strengths are proportional to the amount of glass present in the laminates and vary from 43,360 to 54,720 pounds per square inch. Compression strengths as high as 56,820 and flexural values between 45,350 and 84,600 pounds per square inch are obtained. Impact strengths of unnotched specimens range from 28.82 to 31.25 foot-pounds. Modulus of elasticity is 2,200,000 pounds per square inch and average specific gravity is 1.75. These values are for cross-

laminated cloth. Strength values approximately twice as high may be obtained with parallel-laminated cloth.

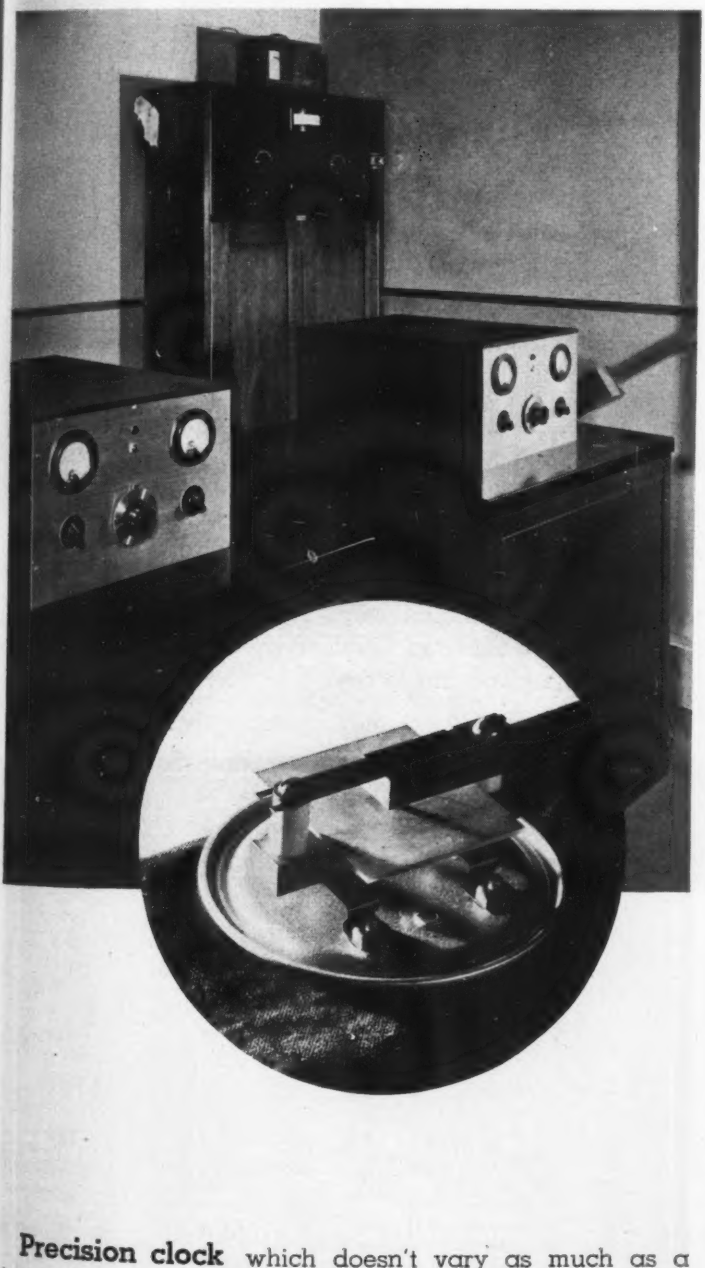


Tracer mechanism, shown schematically at right, controls contour machining of irregular surfaces such as propellers, dies, and cams. Designed by Westinghouse, the mechanism is electronically actuated. Movement of the tracer across a model or templet affects the position of a voltage regulator which through an electronic amplifier moves the cutting tool to duplicate the surface of the model. Accuracies of .003-inch are possible with feeds of 20 to 30 inches per minute.

Cam-operated, the shape-turning mechanism below consists of three elements: One controls the shape of cut, another regulates the number of repetitions in a revolution, and the third controls the contour generated on successive diameters. Mounted on carriage cross-bridge, tool-actuating mechanism is guided in shaper-like strokes by a cam follower which is adjustable from 0 to 2 inches. This motion governs only the shape of a single element or unit of the desired pattern whether oval, triangular,

square, hexagonal or nongeometric.

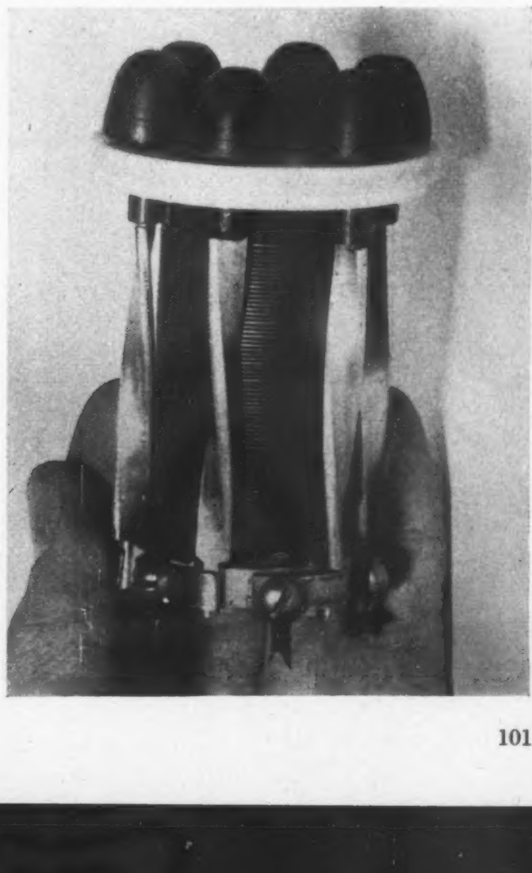
Gear relationship between cam and spindle determines the repetition. A single motor powers the gear changes giving a range up to 500 shapes or tool actuations per revolution of the work. The stroke-compensating device makes it possible to maintain the same shape over a constantly increasing or decreasing diameter of the work piece. Irregular contours are obtained by the use of a metal templet. Smooth blending of surfaces or sharp, clean-cut corners in recessed or exterior angles are obtained as well as exact quantity duplications of shapes.



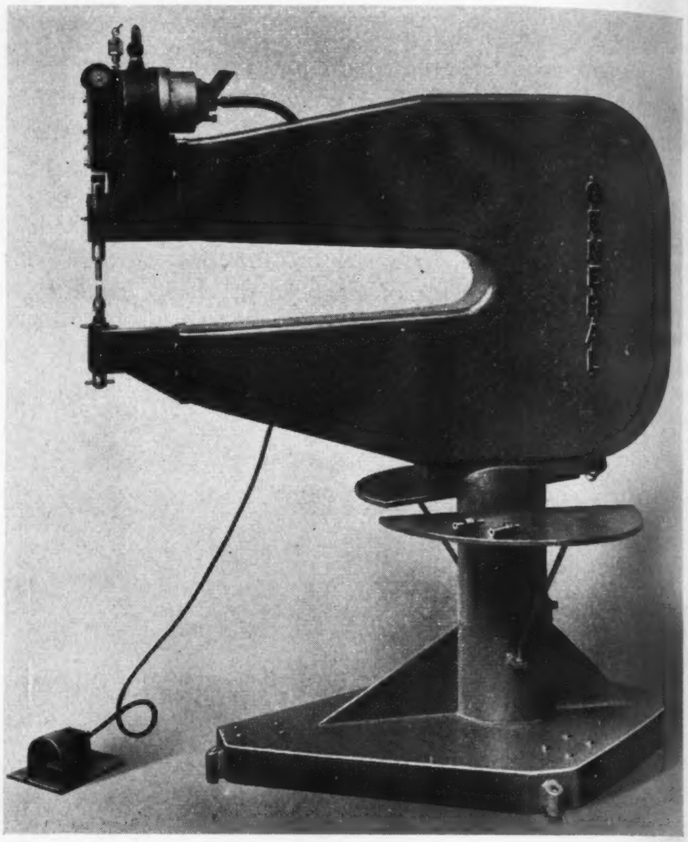
Precision clock which doesn't vary as much as a thousandth of a second a day has no pendulum, weights nor springs. Its controlling mechanism is a small plate of quartz a little larger than a postage stamp and about 1/32-inch thick. This quartz, shown in the insert above, is enclosed in a sealed container within which the temperature is maintained constant to within a hundredth of a degree. The container and its associated vacuum-tube circuits are enclosed in a metal case which rests on a vibration-proof table. Designed by Bell Telephone Laboratories, four of these assemblies are installed in a room whose temperature is maintained constant within half a degree. Two of the assemblies are shown at left. The apparatus in the rear corner of the room maintains constant voltages for the electrical circuits associated with the crystals.

In an adjacent room, three panels carry instruments for intercomparing the rates of the four crystals and the Naval Observatory time signals and for other performance records. One of the crystals supplies the frequency for a synchronous clock. The crystals operate at 100,000 cycles per second, but the frequency driving the clock is a 100-cycle submultiple of the crystal frequency. The instrument for intercomparing the rates of the four crystals will show deviations of any one relative to any of the others of as little as .00001-second.

Twisted-bar contactors, below, instead of the usual bar and slider arrangement, simplify the design of the multiple potentiometer or rheostat and provide a more compact unit than conventional meth-

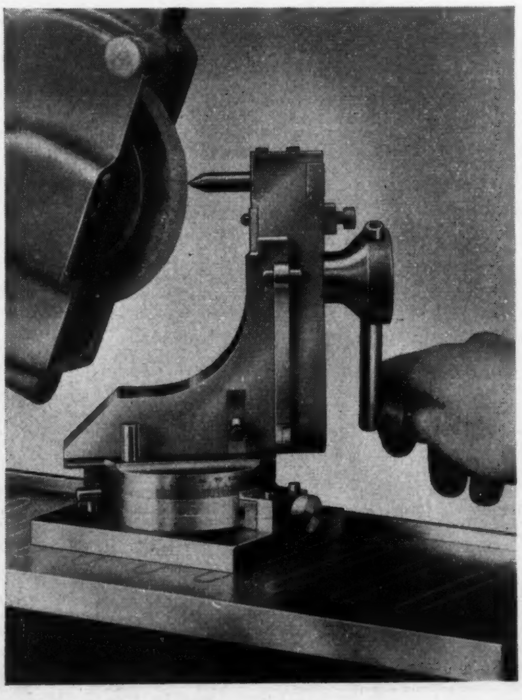


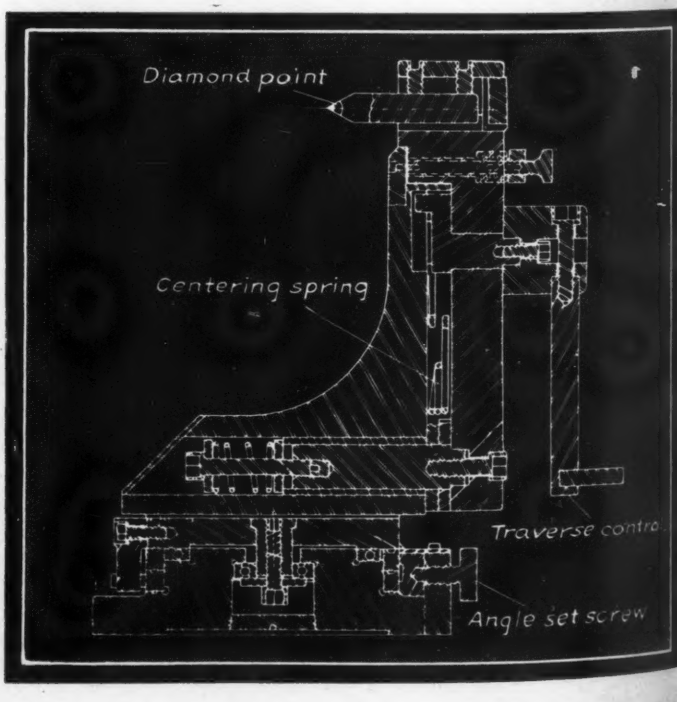
ods. In the device, developed by the American Pattern and Manufacturing Co., the contactors roll upon a single resistance coil in such a way that successive convolutions of each bar control the resistance of its circuit. Spring loading at bottom of bar maintains contact pressure on bar at point of contact and furnishes tap terminal.



Serving as an air accumulator on riveter at right, the rolled-steel pedestal obviates the space and material which otherwise would be required in providing protection against excessive pressure drop in the pneumatic system. Designed by the General Engineering Co., the machine is of welded-steel construction so designed that deflection at maximum pressure is negligible. Operating at 90 pounds air pressure, the machine has a stroke adjustable between $1\frac{5}{8}$ and $\frac{1}{2}$-inch to provide the power necessary for riveting $\frac{1}{4}$-inch, 24 ST aluminum.

Pivoted action instead of sliding dovetails provides smooth action of dresser below for forming straight faces or angles on grinding wheels. Dresser is fed across the face of the wheel by a crank and cam arrangement. Pivot is returned to neutral by a torsion spring. Error due to the transcribed arc is negligible on narrow wheels, being only .000015-inch on a $\frac{1}{2}$-inch face. Convex or concave radii are generated by swivel base which has micrometer dial and pins for stops so that a face and radius may be blended together by the combined action of the pivot and swivel.





How Loads and Enclosures Affect Motor Performance

By G. B. Carson
Director of Research

and L. C. Cole
Chief Engineer
Cleveland Automatic Machine Co.

BY FURNISHING more performance and mechanical data on standard motors the electrical manufacturer could do much to aid the builder of automatic machinery. For example, we recently had a problem in which the WR^2 values for the motor armature and shaft had to be known and were surprised to find that no tabular data were available from the manufacturer. Inclusion of such information on standard motor data sheets would be helpful and might lead to greater accuracy in estimating the type of motor necessary for each application.

In this connection, a problem of adapting motors to reversing duty came up for which the answers to the following questions were desired:

1. How many times per minute will a standard motor reverse with a given external WR^2 load without overheating?
2. How long will it take a standard motor to reverse from full forward to full reverse, with a given external WR^2 load?
3. How many revolutions will a standard motor make in going from full forward to stop and from stop to full reverse with a given external WR^2 load?

Because there were no general solutions to these problems available, we set up a testing procedure for various motors, and obtained the results shown in *Fig.* 1 for the time required to reverse vs. various WR^2 loads.

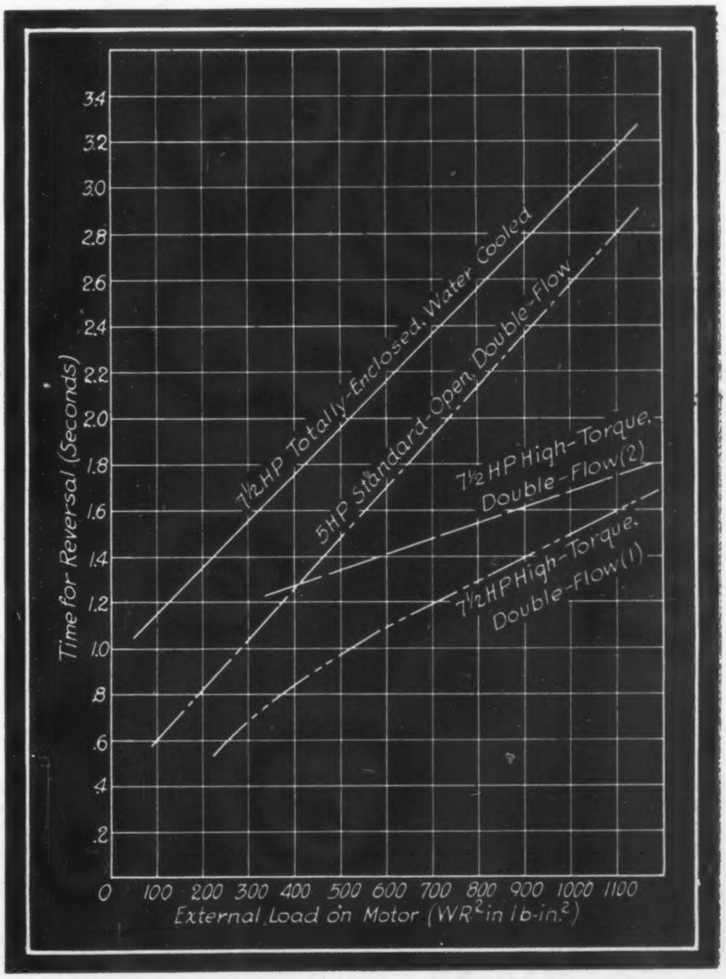


Fig. 1—Time for complete reversal at various external inertia loads. All motors are rated at 1750 rpm

Also, a series of tests to determine heating effects in open air produced the curves shown in *Fig.* 2. Data such as these are useful to predict motor performance for any known WR^2 load external to the motor.

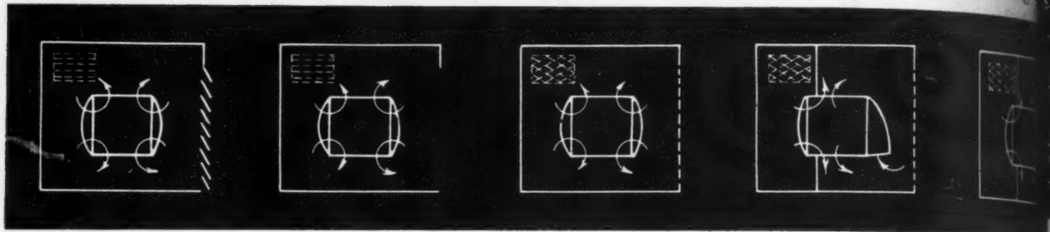
Ambient temperature, particularly in a closed machine base, might be 66 degrees Cent. (150 degrees Fahr.) or higher. We were told, however, that 95 degrees Cent. (203 degrees Fahr.) total temperature "on the stator" would be satisfactory for standard wound motors. Since electrical breakdown can be caused by overheating of insulation at any point, it seems risky to apply a motor which has a 95 degrees Cent. maximum temperature "on the stator" when other points on the motor may be up to a temperature of 150 degrees Cent. (302 degrees Fahr.). We realize, of course, that hot spots on the inner surface of the stator may be expected, and will do no particular harm if the windings are not overheated. It is our experience, however, that winding end loops run about 16 to 20 degrees Cent. (29 to 36 degrees Fahr.) hotter than external stator temperature. Premature breakdown is thus indicated, if peak permissible temperatures are used "on the stator".

Since motors must be tucked in wherever they can be fitted into machine bases, beds or columns, ventilation becomes a major problem. It is frequently impossible to have cross ventilation in such spaces on automatic ma-

From a paper presented at the Machine Tool Forum held at the Westinghouse Electric & Manufacturing Co.

TABLE I—Motor Enclosure Heatin[g]

Design



Motor					
End Bells	Standard	Standard	Standard	Drip-Proof	Stand[ard]
Splash Shields	With	Without	With	With	Witho[ut]
Ventilation	Double-end	Double-end	Double-end	Double-end	Doubl[e-end]
Enclosure	Louvered	Open	Grill	Grill, Baffle	Grill, [...]
Max. Temp.					
Motor (*F*)	Overheated	185	183	176	163
Enclosure (*F*)	174	152	149	125	134
Time to Reach					
Max. Temp. (*hr.*)	1.6	3	4.5	4	3.5

*Upper-half of end bell is blanked off.

chines. Further, because of reversing duty, built-in blowers are usually of the rather inefficient straight-vane type, which further emphasizes the need for proper air flow studies and attention to the design of louvres which allow air circulation in the enclosure.

Results obtained on motor temperatures from tests of a 7½ horsepower squirrel-cage motor rated at 1750 r.p.m., with double-end ventilation, are shown in *Fig.* 3, operating on a reversing-duty cycle which is as follows:

1. Motor runs forward 15 seconds with 1350 lb-in.^{2} for the WR^2 external load
2. Clutch shifts, cutting down speed of external load
3. Motor runs forward 15 sec with 954 lb-in.^{2} load
4. Motor reverses
5. Motor runs reverse 15 seconds with 954 lb-in.^{2} load
6. Motor reverses
7. Motor runs forward 15 sec with 954 lb-in.^{2} load
8. Clutch shifts, changing load speed to high value
9. Cycle repeats.

Comparative results obtained on a motor of similar size and power but with single-end ventilation, are shown in *Fig.* 4. Obviously, there is no reason to be dogmatic about single-end vs. double-end ventilation. Either produces good results if properly designed. In both cases, however, a standard open-end bell should be avoided on the outboard end of a motor to be used in an enclosure.

These tests show that the style end bell shown in *Fig.* 5, which we have chosen to call the "half-moon" type, produces the best results from the standpoint of motor cooling. The improvement occasioned by bottom entry of the air to the motor can be seen clearly by further reference to *Fig.* 4. Curve 1 shows motor temperature when the entire outboard end bell was open, while curve 2 shows the temperature with the two top openings of this end bell blanked off.

Effect of enclosures on motor temperatures were studied and tests developed to determine the best design for a given motor. The original enclosure was substantially cubical with a full set of louvres on the outboard motor end and one small louvred vent at the shaft

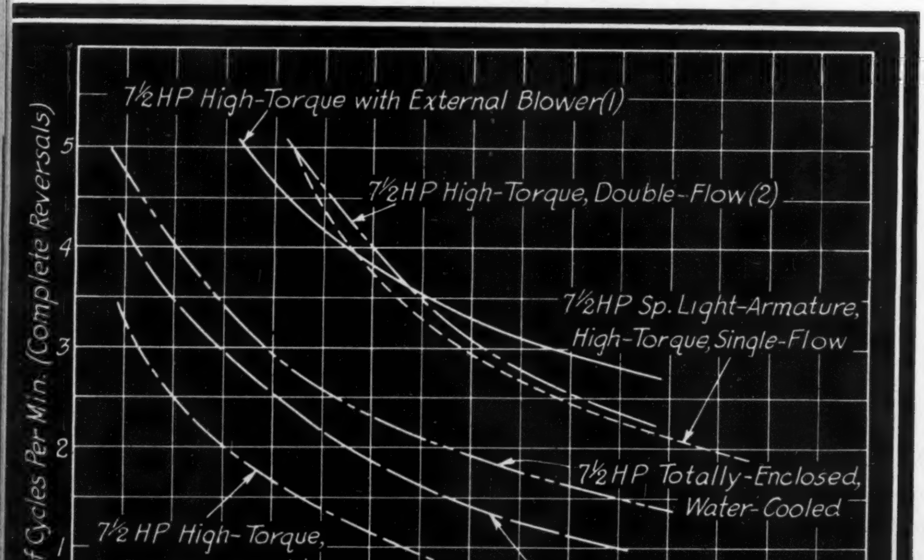
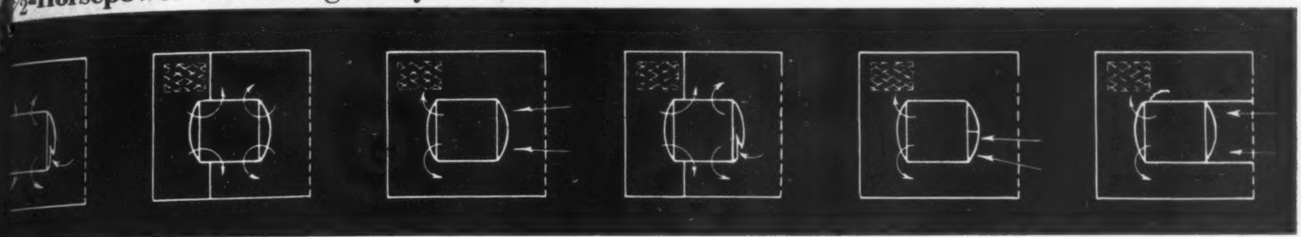


Fig. 2 — Left — Number of complete reversal cycles permissible without overheating. All curves are for 1750 rpm motors of the types indicated

½-Horsepower Reversing-Duty Motor



-Moon h ble-end	Standard With Double-end	Standard Without Single-end	Half-Moon With Double-end	Standard* Without Single-end	Standard Without Single-end
l	Grill	Grill	Grill, Baffle	Grill	Grill, Duct
60 25	160 139	159 130	158 130	148 122	128 108
7	3.5	9	8	4	8

end of the motor near the top of the enclosure.

The louvres were soon abandoned in favor of expanded metal grills over the openings, since the restriction to flow through the cast louvres was excessive. The variations tried in the design of the housing are illustrated in TABLE I. Here the important influence of a baffle can be seen. A transverse baffle was placed across the enclosure, in such a way that the double-end circulation motor pulled all its air for the shaft end through the small vent at the side of the enclosure, and discharged through the grill at the outboard end. This arrangement resulted in a 20 degrees Fahr. drop in motor temperature and a 15 degrees Fahr. drop in ambient temperature compared to the unbaffled enclosure. These improvements were not sufficient to justify baffle costs.

Generally speaking, these tests show single-flow ventilation to be slightly better than double-flow ventilation in enclosures which are not cross vented. Further, if the air flow is organized, so that there is no recirculation, as was the case of the single-flow motor with the duct leading from the rear of the motor to the grill of the enclosure, much cooler operation results. The addition of the duct made a reduction in motor temperature of 20 degrees Fahr. over the next best condition, and a reduction in ambient temperature of 14 degrees Fahr. by the same method of comparison. Such design, obviously, poses problems from the standpoint of adjustment of the motor for belt tensioning, so it is suggested that such duct work be carried only to a clearance distance inside of the grill.

The most important conclusions that can be drawn from motor heating tests are:

1. Single-flow ventilated motors lend themselves best to blind enclosures, while double-flow motors are also quite satisfactory where some enclosure cross venting can be provided
2. Air flow must be studied by the machine manufacturer and baffles or ducts added to prevent recirculation of air through the motor in the severe cases
3. Much could be gained by more efficient motor blower design, from air flow standpoint.

Variable-speed direct-current motor feed drives have

TABLE II

Usable Speed Range of Variable-Speed Drives vs. Low Speed
(High Speed = 2000 RPM)

Usable Low Speed	Range	Maximum Number of RPM Permissible Variation (Zero to Full Load)
200	10:1	10
100	20:1	5
80	25:1	4
60	33:1	3
40	50:1	2
20	100:1	1
10	200:1	.5

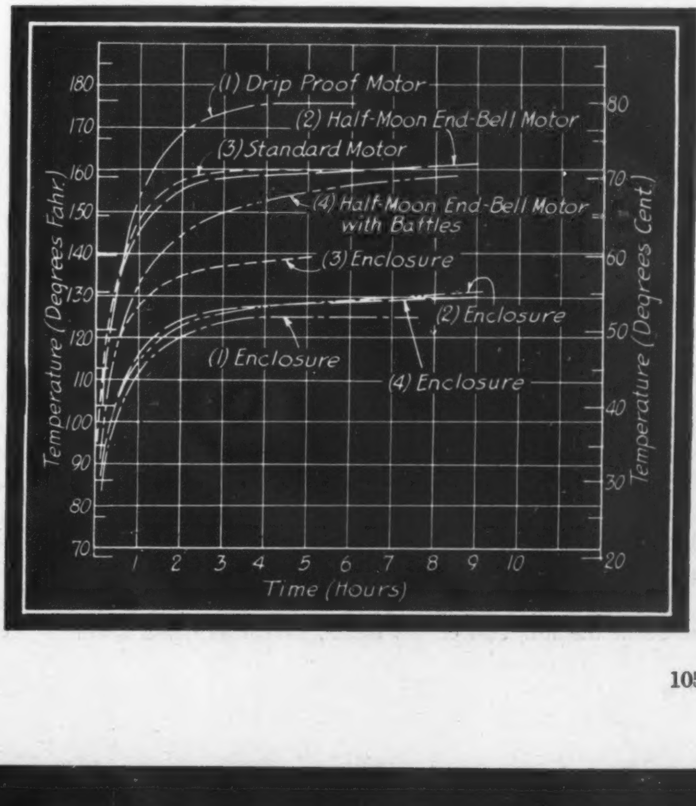


Fig. 3—Right—Temperature of motor and enclosure for one-minute cycles, reversing duty. Motor is 7½ horsepower, 60 cycle, 220-240 volt, 1750 rpm with double-flow ventilation

Table III

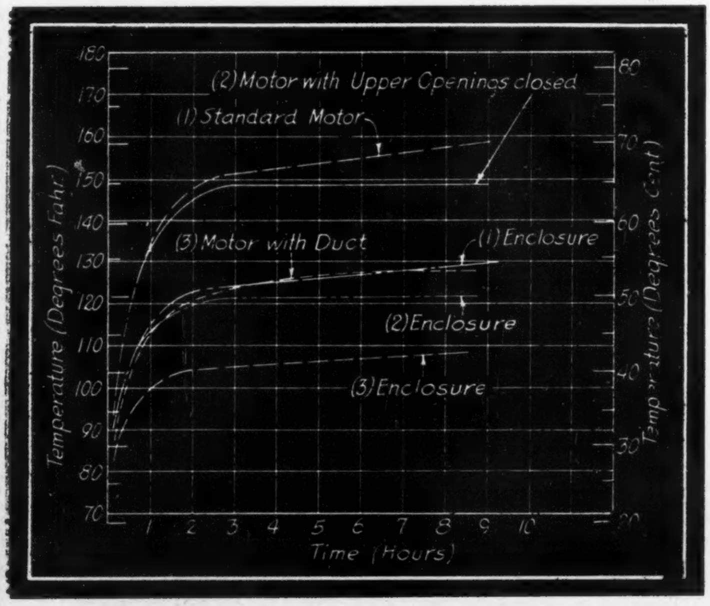
Size Requirements of Variable Speed Drives
(Compared to a Standard Alternating-Current Motor of Same Horsepower*)

Component Part	TYPE OF DRIVE: Electronic (%)	Motor-Generator (%)
Drive motor	130	171
Power source	115	275
Controls, regulation	725	360
Total	970	806

*All figures are in per cent of alternating-current motor size.

been applied for many years, particularly to planers where acceleration is more important than exact speed regulation. Requirements for such a feed drive are:

1. Speed regulation must be within plus or minus 5 per cent over the entire usable range
2. Variations caused by warmup must not produce changes in excess of the above, when added to speed changes with load
3. Cycle history, that is, the effect of preceding loads and speeds on succeeding loads and speeds in the cycle, must not produce changes in excess of the values stated in Point 1, when considered additive to both 1 and 2 variations
4. Mechanical inaccuracies (looseness) in the potentiometer or rheostat construction must not produce



greater speed variation than plus or minus 5 per cent when considered in addition to regulation, warmup, and cycle history
5. Circuits and electrical equipment must be sturdy, and so designed that local electrical service help can maintain the entire circuit and equipment
6. The apparatus preferably should not occupy more than double the space for a standard motor and controls.

Our experience in testing mechanical and electrical variable-speed devices is that *speed regulation* is the factor which limits range. The same difficulty is experienced with hydraulic units. By the term "speed regulation" is meant any speed change versus load over repeated cycles for any cause whatsoever.

Good regulation at low speeds is especially important, since at the low end of the range, each successive lower usable speed extends the range, as shown in Table II.

It is insufficient to speak warmly of the wide range of a variable-speed device. Wide range in itself is not usable in feed drives if the percentage regulation at the low end of the speed range becomes increasingly worse as is often the case.

Further, it is one thing to build one variable-speed drive to close tolerances of performance, and quite another matter to build, on a production basis, several units to the same tolerances. It has been our experience that duplication of performance from unit to unit is as great a problem for the electrical manufacturer as the achievement of close speed regulation. It is necessary, in our opinion, for the electrical manufacturers to produce a unit which the machine manufacturer can use without reworking on his part before installation.

The space occupied by electrical equipment is becoming a matter of increasing concern to the automatic machine designer. Better styling prohibits the scattered placement of electrical equipment at odd locations around and on the machines. Sound engineering dictates that

Fig. 4—Left—Temperature of motor and enclosure for same cycle as for Fig. 3. Motor is same size but has single-flow ventilation

Fig. 5—Below—Half-moon type of end bell produces effective motor cooling

apparatus requiring electrical maintenance be centered in as few locations as possible.

Table III is a comparison of approximate requirements of the motor-generator, and the electronic type of variable-speed direct-current drives. The requirements are based on the size of a standard alternating-current motor of the same horsepower capacity. Volumetric tabulations in the table show why the machine manufacturer frequently finds it difficult to adapt electrical variable-speed devices to his machines. (The reason the drive motor is relatively larger in the case of the motor-generator type of drive than in the electronic type of drive is that the designers of the former used a larger frame size per horsepower than did the designers of the electronic unit.) Mechanical and hydraulic devices in some cases occupy only 300 to 500 per cent of the same space.

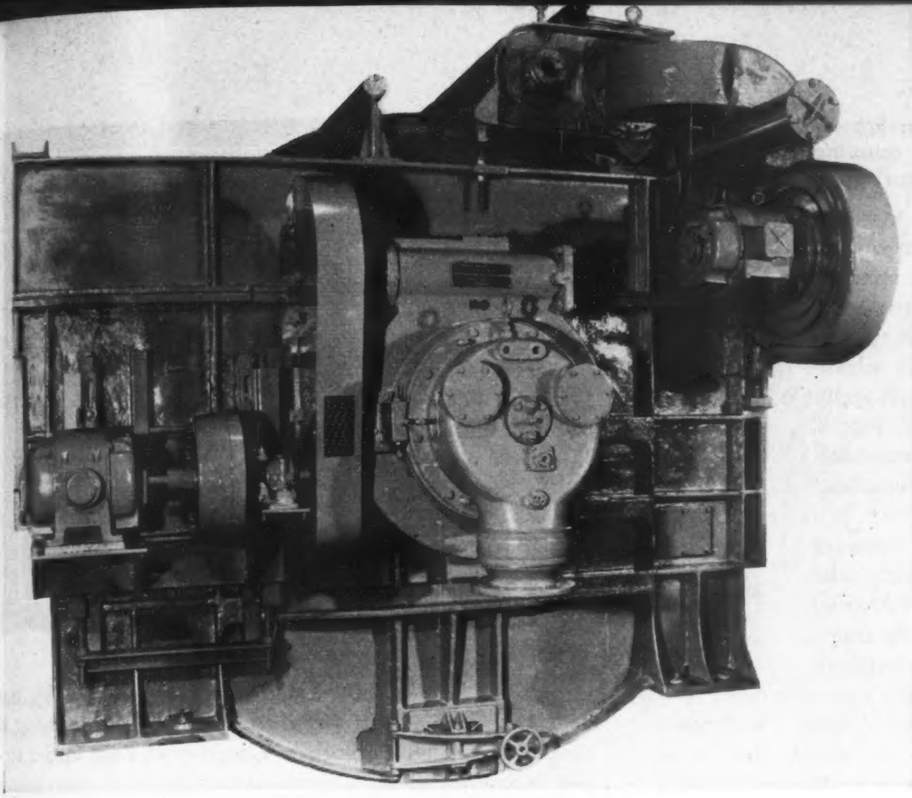


Fig. 1—Left—Fluid coupling with scoop control which changes amount of fluid in the working circuit furnishes variable-speed drive for filter on paper-making machine

Fig. 2—Below—Quantity of fluid in coupling is controlled by gear pump. As amount is reduced the slip increases, providing variable speed

Specifying Variable-Speed Drives

Part III—Hydraulic

By Colin Carmichael

HYDRAULIC speed-changing transmissions are of two basic types—hydrokinetic and hydraulic displacement. The hydrokinetic types include elements corresponding to a centrifugal pump and a hydraulic turbine, while the hydraulic displacement types consist essentially of a piston pump and fluid motor, either one or both of which may have variable stroke. Keeping in mind the distinction between variable and adjustable, it may be noted that hydrokinetic transmissions are essentially variable speed in which the speed varies with the load and, in some cases, with an adjustment. Hydraulic displacement type transmissions are adjustable speed inasmuch as the output speed, once set, remains nearly constant regardless of the load.

Simplest of the hydrokinetic drives is the hydraulic coupling or fluid drive familiar to automobile drivers as the fluid flywheel

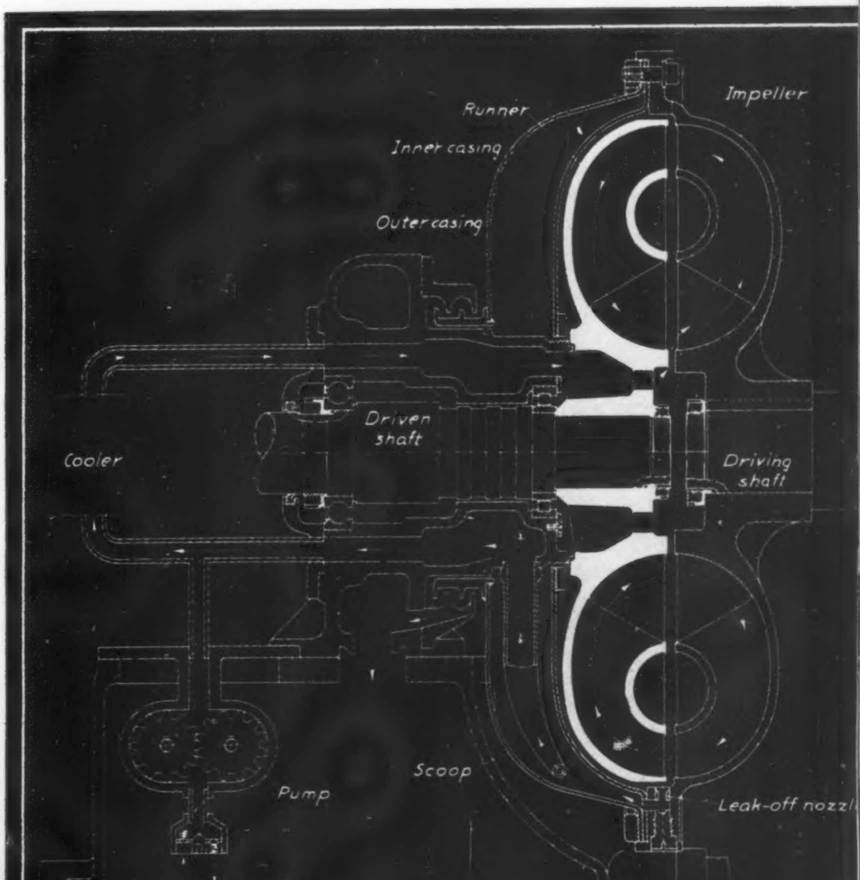
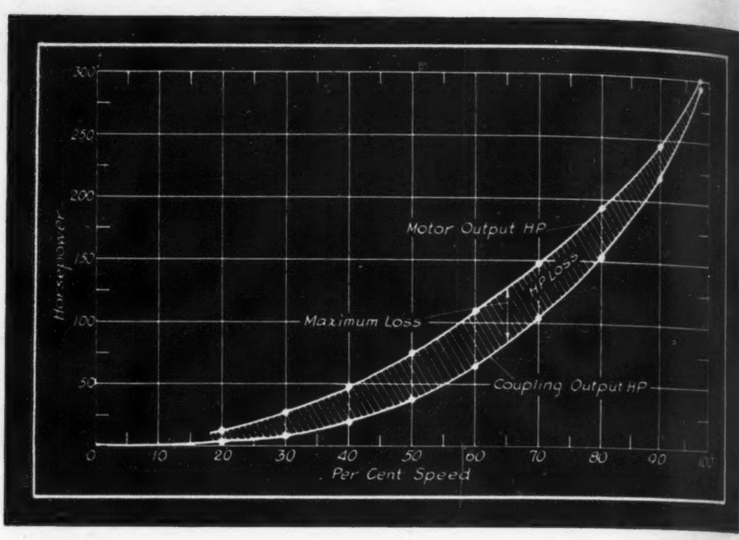


Fig. 3—Right—Curves show horsepower loss for a variable-speed hydraulic coupling applied to a 300-horsepower fan drive



or fluid clutch. Although it is not capable of torque conversion, having no intermediate guide vanes to take the torque reaction between the impeller and the runner, the hydraulic coupling has distinct advantages that make it desirable for such applications as paper-making machinery, *Fig.* 1, aircraft test stands, rotary kilns, mechanical draft equipment, centrifugal pumps and airplane superchargers.

Variable-speed control of this type of coupling is effected by changing the amount of fluid in the working circuit, *Fig.* 2. When running full the coupling transmits the full torque for which it is designed, with a slip which usually is less than three per cent. Removal of part of the working fluid reduces the torque-transmitting capacity, resulting in slip which may be as high as 80 per cent, corresponding to a five-to-one speed reduction. Performance is given by an equation of the form

$$T = K\rho\, N^2 D^5 f(s) \qquad (1)$$

where T is the torque, ρ the density of the hydraulic fluid, N the input revolutions per minute, D the diameter of the coupling, s the slip and K a constant which is a function of the coupling design and of the amount of fluid contained in it. For small slips (up to six per cent) the torque is in linear proportion to s. Inasmuch as input and output torque are at all times equal, efficiency is equal to the speed ratio or $1-s$.

Shown in schematic cross section in *Fig.* 2, the variable-speed hydraulic coupling includes the usual impeller (input) and runner (output) elements through which fluid circulates by virtue of the difference in speed as shown by the arrows. Kinetic energy acquired by the fluid in the impeller is absorbed by the runner, causing it to rotate and deliver torque. Quantity of fluid in the circuit is controlled by a positive-displacement gear pump which adds or removes oil as required. A certain proportion of the fluid continually escapes at the leak-off nozzles into the space between the inner and outer casings, after which a stationary scoop tube picks up the fluid and circulates it through an oil cooler and back into the coupling as shown. The oil pump can be driven either by a continuously running motor or by a reversible motor depending on the type of control used.

Scoop Tube Provides Simple Control

Simplified means for varying the quantity of fluid in the working circuit are employed in another type known as the scoop control coupling which dispenses with a pump. Space within the outer casing is made more than large enough to contain the entire quantity of fluid and serves as a rotating reservoir in which the fluid is held at the outer diameter by centrifugal force. The scoop tube is so mounted that it can be swung entirely free of the fluid, leaving the working circuit empty and incapable of transmitting torque. The tube can be swung into the rotating oil so that fluid is picked up and transferred to the working circuit, the amount of oil in the circuit depending on the location of the tube. Runner or output speed is varied by the quantity of oil in the working circuit as determined by the position of the scoop tube.

This type of coupling is of lightweight construction and often can be mounted directly on the motor shaft. The paper-making machine illustrated in *Fig.* 1 employs such a coupling for the filter drive, shown at the left of the illustration. The fluid

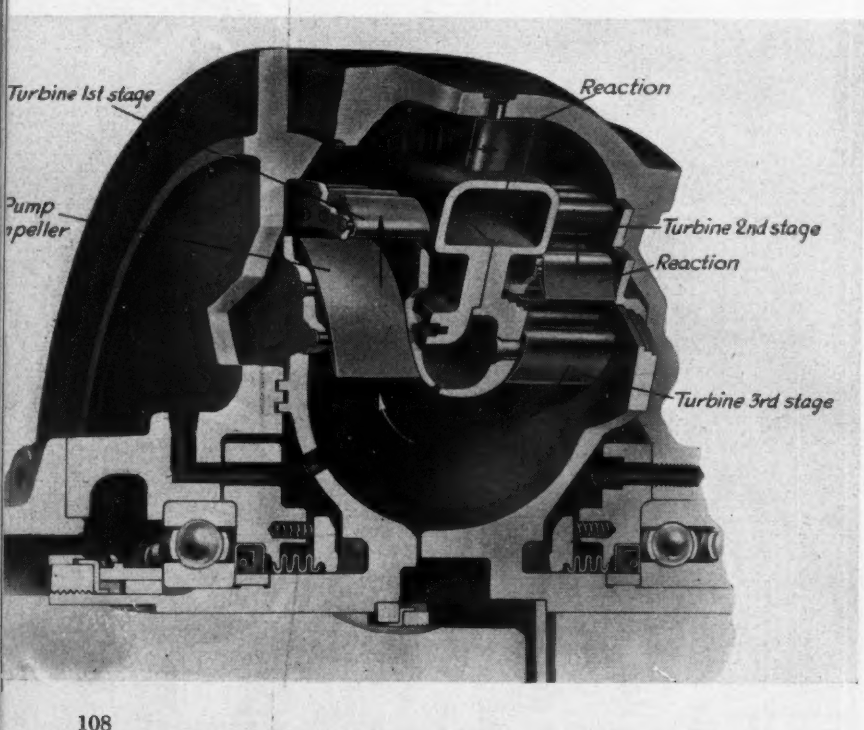


Fig. 4—Left—Torque converter employs single-stage pump and three-stage turbine. Stationary reaction blades absorb torque difference between input and output

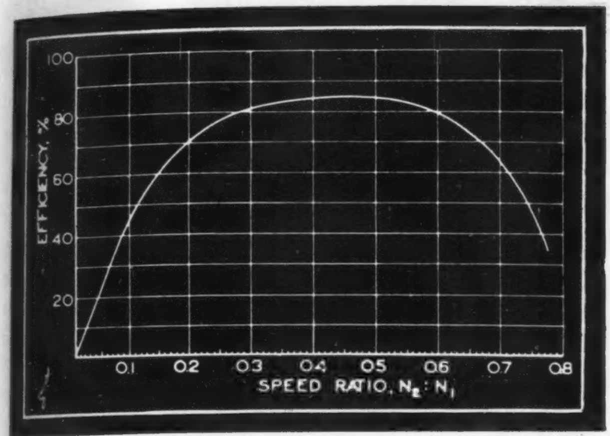


Fig. 5—Efficiency of three-stage torque converter as a function of speed ratio between output and input shafts

coupling provides variable speed for the filter drum to hold good mat thickness with fluctuating stock flow. A wire attached to a float in the tank adjusts the drum speed by operating the scoop tube lever so that a steady liquid level is held. The 12-inch scoop control coupling is rated at 10 horsepower at 1200 revolutions per minute.

In selecting a coupling for variable speed it is important that the horsepower, torque and speed requirements be known accurately. If the horsepower is greater than anticipated, the slip will have to be high in order to handle the torque (Equation 1) while the oil cooler and leak-off nozzle sizes selected may be too small to handle the heat load. Torque characteristics, whether constant or varying, should be known since the speed control range of the coupling is limited by the torque requirements. For example, on constant torque duty the coupling should not be selected for greater than three to one reduction due to the high heat load encountered at reduced speed, the speed reduction being limited by the quantity of oil that can be circulated for cooling purposes. On fan loads or loads of a similar nature where the torque varies as the square of the speed, a reduction of five to one is obtainable. It is not recommended that speed reduction below this be used because of the windage horsepower developed in the coupling which often is sufficient to drive a fan at ten to fifteen per cent speed, depending on the type of bearings used and the alignment. At speeds below twenty per cent the quantity of oil circulated is so small as to make control highly sensitive and often quite difficult.

Typical performance curves for a 300-horsepower fan drive are shown in *Fig.* 3. Horsepower absorbed by a fan is proportional to the cube of the speed and is plotted as the coupling output. Motor horsepower is found by dividing the coupling output by the efficiency which is equal to the speed ratio. The horsepower difference between the two curves represents the loss which appears as heat in the oil of the coupling and has to be dissipated in the cooler. Maximum value of this loss occurs at about 65 per cent speed and is equal to approximately 45 horsepower as shown on the curve sheet, *Fig.* 3. This figure checks approximately with actual tests which show that the heat load amounts to about 17 per cent of full load horsepower. Assuming the maximum heat load to be, say, 50 horsepower, the cooler must be specified to handle $50 \times 2545 = 127{,}250$ Btu per hour. Although the efficiency at low speed is relatively low, the driving motor horsepower over the entire speed range is lower than it would be if the fan output were regulated by a damper or if it were driven by a variable-speed slip-ring motor. In addition to the variable-speed characteristics already noted, the hydraulic coupling has the property of almost completely eliminating shock load and torsional vibration between the driving and driven shafts.

Torque Converter Employs Reaction Element

Hydrokinetic torque conversion between the impeller and runner necessitates the addition of a stationary reaction element to absorb the difference in torque. Principal features of this type of transmission are illustrated in *Fig.* 4 which shows a cutaway view of a unit employing a single-stage pump and a three-stage turbine. Torque increase is generated as the circulating fluid passes alternately through and reacts against the stages of the turbine and stationary blades of the housing. Available torque depends upon the speed ratio between input and output shafts. This extends from a maximum of better than five to one, obtained at stalling, down to the equivalent of the input torque, obtained at approximately two-thirds of the input speed. Efficiency of the converter as a function of speed ratio is shown in *Fig.* 5, from which it is evident that the efficiency is maintained at a high value over a wide speed range. Inasmuch as the torque multiplication is equal to the efficiency divided by the speed ratio, a curve of torque versus speed may readily be constructed from this diagram.

Hydraulic torque converters find their principal appli-

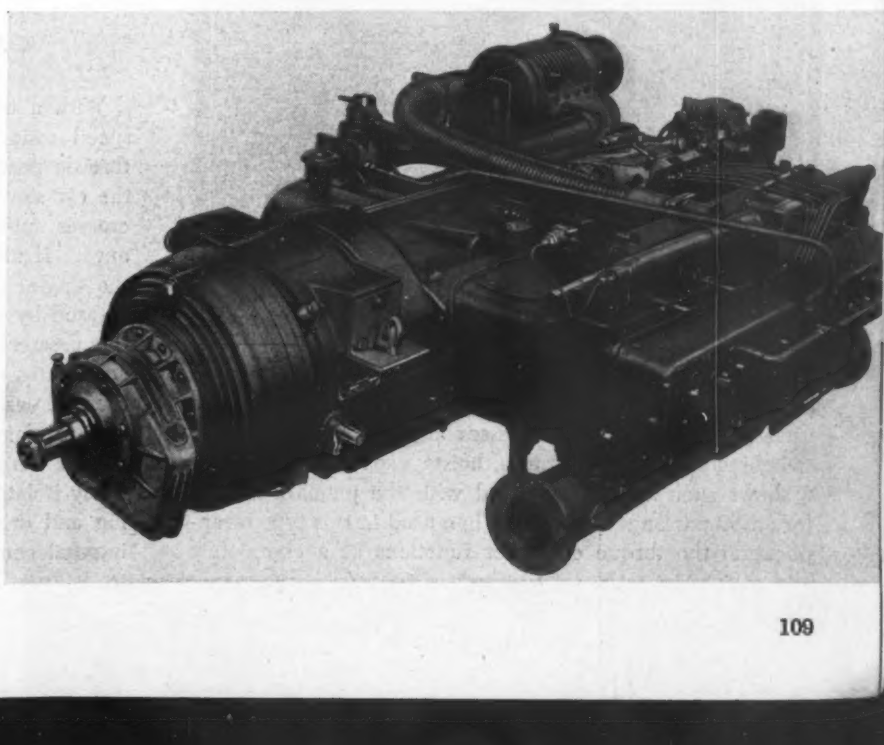


Fig. 6—Right—Torque converter is bolted to flywheel housing and flywheel of pancake engine for an 80-passenger railcar

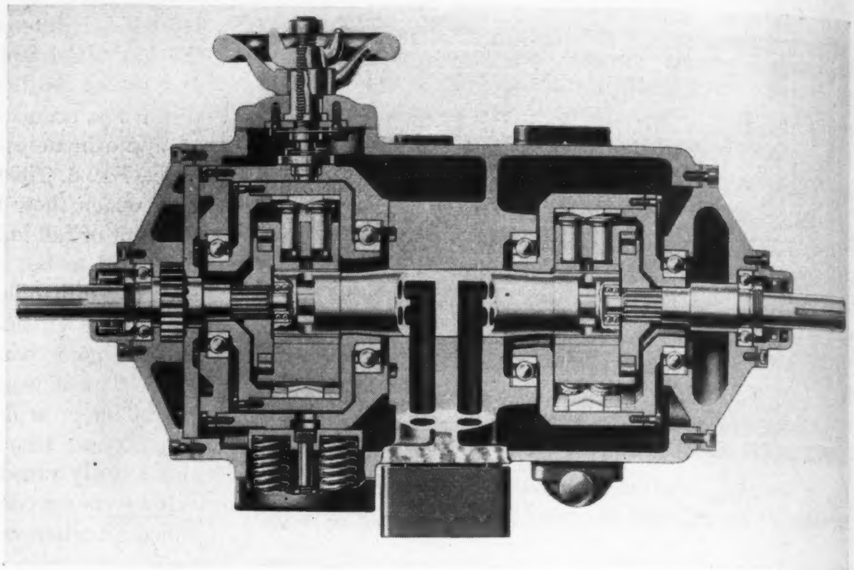


Fig. 7—Right—Fluid power transmission employs variable-displacement pump and constant-displacement motor with radial pistons

Fig. 8—Below—In the parallel-piston transmission, stroke of pump pistons is varied by tilting socket ring which controls their movement

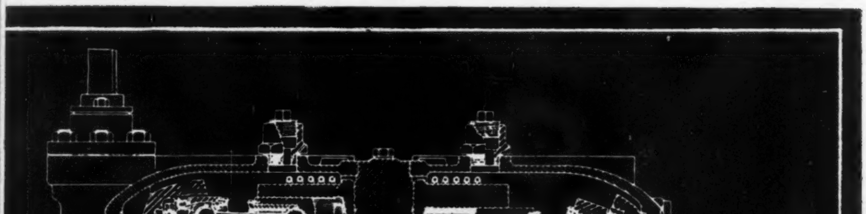


Fig. 9—Below—Efficiency curves for two typical displacement-type transmissions at constant torque output

cations to internal combustion engine drives and have been used fairly extensively in busses and railcars as well as switching locomotives, cranes, hoists, excavators, etc. *Fig. 6* shows such a unit associated with the pancake engine for an 80-passenger railcar. When used in this type of application the torque converter functions as a completely automatic self-changing transmission. When the efficiency drops below 70 per cent, corresponding to speed ratios above two-thirds, direct drive may be employed to maintain high efficiency and reach higher speeds.

Hydraulic characteristics of the converter are such that the power absorbed by the pump element is proportional to the cube of input speed. With the converter pump capacity matching that of the engine or other drive, the input shaft operates at nearly constant speed regardless of the output speed. Actually, with an engine of normal characteristics, there is speed drop of approximately 25 per cent from the maximum down to the stalling speed. Inasmuch as the efficiency of the converter is a function of speed ratio, *Fig. 5*, high efficiency at low output speeds and loads may be maintained by allowing the engine speed to drop so as to maintain a ratio of between .3 and .6, corresponding to an efficiency of over 80 per cent.

Automotive Converter Performance

With a torque converter in an automobile or bus the speed ratio adjusts itself according to road speed and throttle position. Thus when an upgrade is encountered the car slows down until the converter output torque increases sufficiently to overcome the increased car resistance. If at the same time the driver "steps on the gas", the engine speeds up and the driveshaft torque is increased by virtue both of the increased input torque and the greater speed reduction. On a level road, the car accelerates until the output torque drops, on account of the decreasing speed reduction, to the value just necessary to maintain uniform speed.

Like the hydraulic coupling, the torque converter effectively isolates shock and vibration loads between the driving and driven shafts. Thus the output torque from an internal combustion engine and torque converter can be

as smooth as that from an electric motor. Because of the ability to furnish infinite speed ratio (zero output speed) the combination also can be used to hold a load without motion and can provide a jogging action when required.

Hydraulic displacement transmissions result from combining a fluid pump and fluid motor. These may be combined as an integral unit, as in *Figs.* 7 and 8, or may be located a reasonable distance apart and connected by pressure and return piping. Integral units normally are furnished with a variable-displacement pump and a constant-displacement fluid motor, as in *Figs.* 7 and 8. With this combination the output torque is constant, maximum torque being available at all speeds. Thus the transmission unit is essentially a speed-control unit rather than a speed reducer, inasmuch as it is not designed to furnish increased torque at lower speeds. However, it is a highly efficient torque converter and as the output speed is decreased the input horsepower decreases. Typical efficiency curves are shown in *Fig.* 9.

In *Fig.* 7 is shown a transmission employing radial piston pump and motor units. The input shaft, at the left-hand end of the transmission, drives a cylinder barrel which is mounted on a fixed pintle. Radial rolling pistons working in the cylinder barrel are confined by concave reaction rings which engage their mushroom-shaped heads. The rotor is carried in an adjustable slide block which may be moved radially by the handwheel so as to change the eccentricity of the rotor with respect to the cylinder block, thus changing the stroke of the pistons. Intake and discharge ports are provided in the pintle through which fluid is conducted to and from the motor element. Similar in operating principle to the pump, the motor has a fixed stroke, the rotor being mounted in the housing at a fixed eccentricity.

Speed and Torque Characteristics

Speed ratio is inversely proportional to the ratio of displacements and is little affected by load changes. Torque input and output are proportional to the displacements and to the fluid pressure in the system. At zero pump displacement the speed ratio is infinite, hence jogging or inching is possible.

An application of this type of unit to a special Kant-Slip continuous forms printing press is shown in *Fig.* 10. Installed at Standard Register Co. this press, which is one of ten, is capable of printing in two colors, has an imprint unit and numbering, file punching, no-slip punching, cross perforating, lengthwise perforating, and folding units. It must print the forms far more accurately than is expected on the conventional web-type presses. There are six positions on each press for inching purposes, and the chief reason for specifying fluid-power transmissions was to overcome the jerking and consequent out of register which may occur when inching a large machine. Although a high operating speed is not essential on this type of work because the runs are relatively short, these presses operate up to 12,000 impressions per hour.

Control of the output speed in the application just described is effected by an electric geared head motor which changes the stroke of the pump by shifting the slide block which carries the rotor. This control motor is visible in the right foreground of *Fig.* 10, mounted on the side of the transmission unit. Other control methods that can be used include handwheel control on screw shaft, as in *Fig.* 7, wormwheel on screw shaft with handwheel on wormshaft for exceptionally accurate adjustments, hydraulic servomotor, pressure type of control providing speed regulation in response to the load on the output shaft, hydraulic remote control providing remote selection of two predetermined adjustable speeds, and time-clock control for accurate speed regulation in response to a predetermined time cycle.

Drive for a Meisel roll-fed printing press is shown in *Fig.* 11. In this case the pump unit and motor unit are separate and connected by short lengths of piping. The same type of motor control as in *Fig.* 10 is used.

Where constant horsepower rather than constant torque

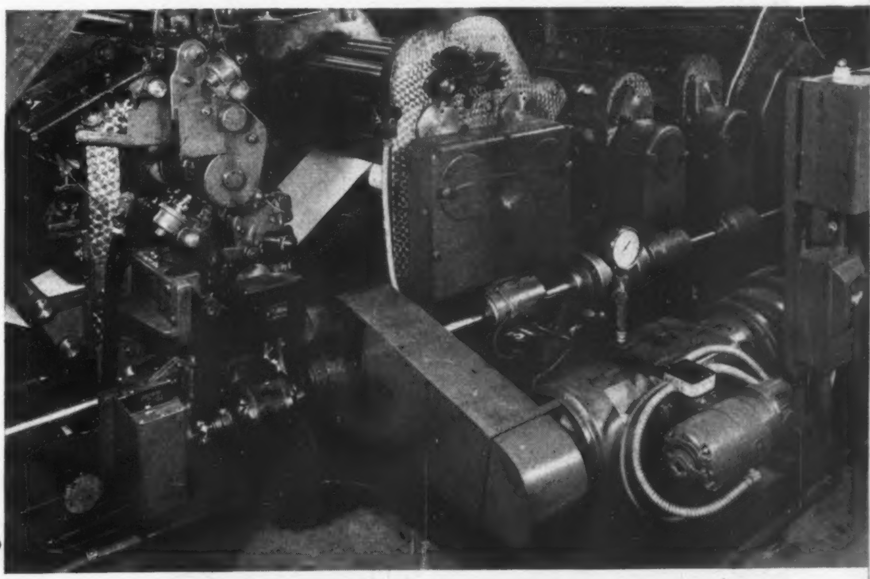
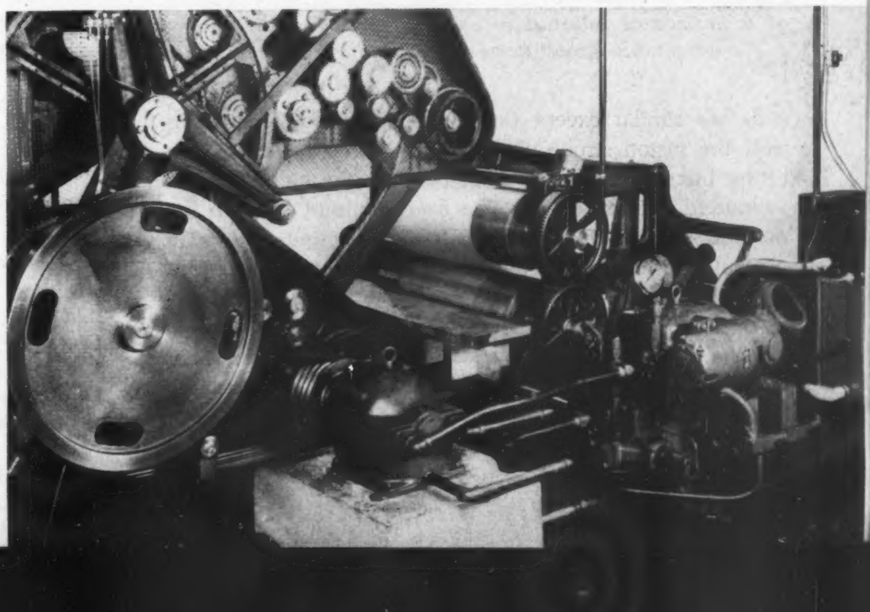


Fig. 10—Above—Hydraulic displacement transmission, right foreground, provides adjustable-speed drive for special continuous forms printing press

Fig. 11—Below—Variable-displacement pump and constant-displacement motor furnish an adjustable-speed drive for this roll-fed printing press



characteristics are desired, a constant-displacement pump and a variable-displacement motor may be used. Inasmuch as the quantity of fluid pumped is constant, such a drive cannot be used for slow speeds and in practice a speed range of 3 to 1 is the usual limit, the output speed increasing as the motor stroke is reduced. The same control methods as in the variable-displacement pump transmissions may be used.

Selection of constant power or constant torque over a wide range in either direction is conveniently obtained by using a variable-displacement pump and a variable-displacement motor. By varying the pump stroke the speed changes but the maximum torque remains constant. Reversing the pump discharge changes the output shaft rotation of the motor. By varying the motor stroke the speed and torque change but the maximum power output remains constant.

A transmission employing axial piston pump and motor units is shown in *Fig.* 8. Input (left) and output (right)

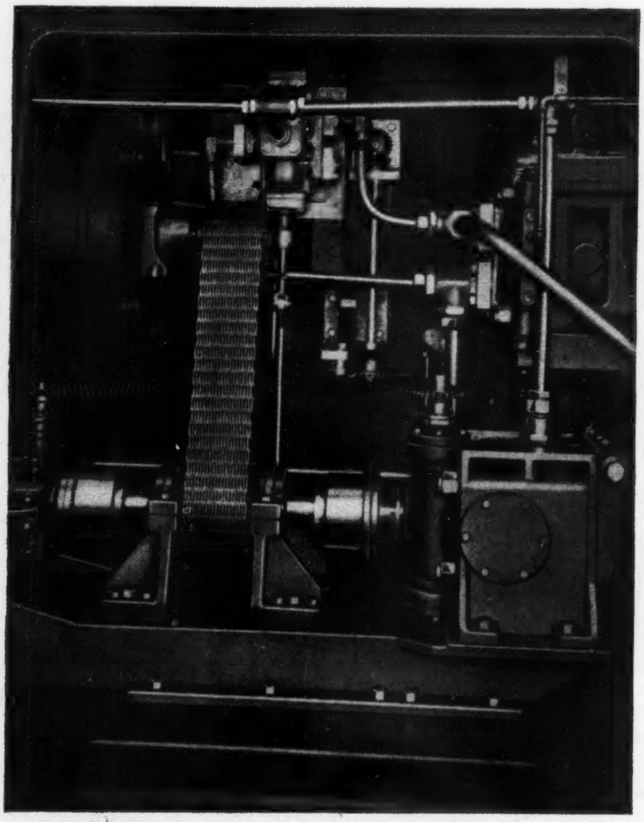


Fig. 12—Variable-displacement pump built into the housing of a horizontal internal grinder is employed to provide adjustable-speed drives for spindle and feed

ends are similar except that the socket ring which controls the piston stroke of the input unit is mounted in a tilting box whereas the socket ring for the output end is supported in the housing at a fixed angle of tilt. In the position shown, the socket ring of the input end is in neutral position so that as the cylinder barrel and pistons rotate no piston movement occurs and no oil is pumped to the output end. As the socket ring is tilted by manual or other control, the pistons start to reciprocate and oil is transferred to the cylinders of the output unit through ports in the central stationary valve plate.

Transmissions of this type may also be applied with the pump and motor unit separate. *Fig.* 12 shows such an application to a Hutto horizontal internal grinder, the drives being fully enclosed in the machine. Spindle speeds from 3 to 96 revolutions per minute are provided, while the feeds may range from zero to 55 feet per minute.

Recent developments in displacement-type hydraulic transmissions as a result of wartime experiences and the influence of aircraft hydraulics have resulted in increased capacity per unit size and weight due to the adoption of higher speeds and pressures. It is of interest to speculate as to the possibilities of applying this type of lightweight transmission to automobiles, busses, railcars, etc. In the first place, the input or pump unit may be attached to the engine while the output or motor units may be coupled to the wheels, using a separate unit for each wheel and avoiding the necessity for a differential drive, differential wheel speeds being obtained by employing suitable valves in the hydraulic circuit. With variable-displacement pump and constant-displacement motor units an infinite number of speed changes, both forward and reverse, are possible and no clutch is necessary since the pump stroke may be made zero for the stop condition.

Automatic Control Possibilities

While such a transmission will furnish speed ratios which are under the complete control of the operator, it may be made fully automatic by the addition of suitable controls. Inasmuch as high reduction ratios ordinarily are needed at low car speeds a hydraulic governor driven at wheel speed could be used to control the pump stroke and therefore the ratio. To take care of the requirements of hill climbing and rapid acceleration, an additional control connected to the throttle or to the inlet manifold vacuum could be used to give higher reduction ratios when the loads are high.

When considering the application of displacement-type transmissions the following information is necessary to form a basis for the selection of the appropriate unit:

1. Characteristics of the driven load
2. Type and speed of prime mover to be used
3. Output shaft speed range desired and whether reversibility is needed
4. Maximum horsepower to be transmitted
5. Maximum torque to be delivered and at what speed; also starting torque
6. Type of service—whether continuous or intermittent
7. Inertia of rotating parts
8. Acceleration and deceleration rates required.
9. Type of control—handwheel, remote or automatic—and functions required
10. Any extremes of temperature or other unusual conditions of operation.

With these facts in their hands the engineers of the transmission manufacturer will be in a position to recommend the proper unit for the particular application.

MACHINE DESIGN acknowledges with appreciation the cooperation of the following companies in the preparation of this article: Hydraulic Coupling division of American Blower Corp. (*Figs.* 1, 2 and 3); Northern Pump Co.; The Oilgear Co. (*Figs.* 7, 10 and 11); Sundstrand Machine Tool Co.; Twin Disc Clutch Co. (*Figs.* 4, 5 and 6); and Waterbury Tool division of Vickers Inc. (*Figs.* 8 and 12).

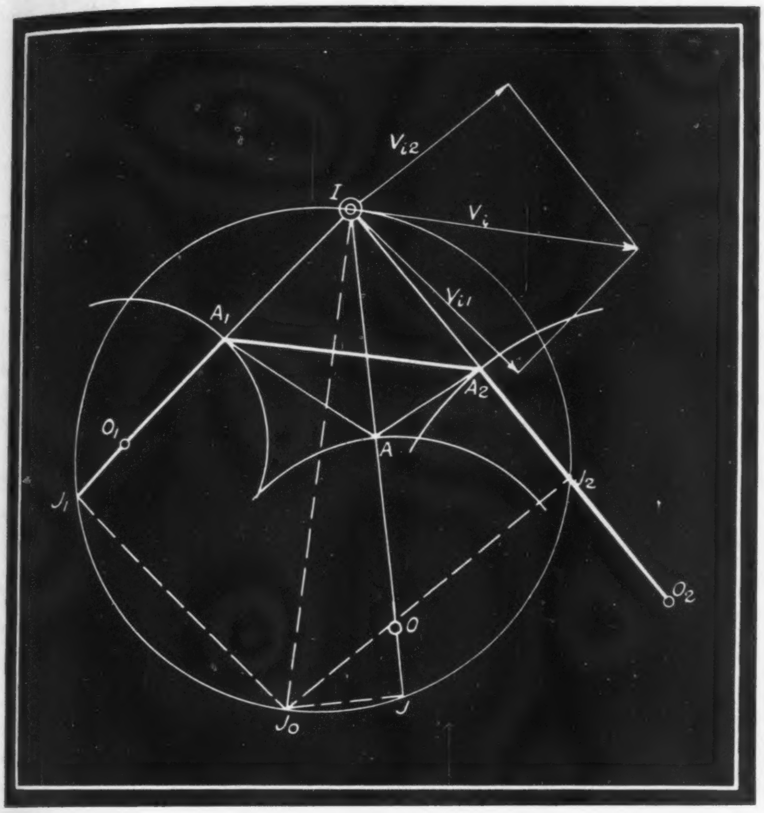


Fig. 1 — Determination of centers of curvature of trajectories from instantaneous center of rotation, for link denoted by A_1A_2

Simplified Method Shortens Acceleration Analysis

By Leon Beskin
Structures Engineer
Consolidated Vultee Aircraft Corp.

WELL-KNOWN graphical methods of velocity and acceleration analysis of mechanisms depend generally on the employment of a step-by-step procedure. Purpose of this article is to indicate how these methods can be extended readily to cases where the conventional step-by-step analysis cannot be applied direct.

In order to make that extension, it is necessary to use the idea of instantaneous center of inflexion, J, of a moving link. Instantaneous center of inflexion is a point, considered as attached to the link, which has a velocity equal to the velocity of the instantaneous center of rotation, with the same direction and sense as the latter. Although the instantaneous center of rotation customarily is thought of as being a stationary point, actually it moves as the linkage moves. The method of calculating velocity of the instantaneous center and locating the center of inflexion is illustrated by the example shown in *Fig.* 1.

The ends A_1 and A_2 of the link A_1A_2 have trajectories indicated by the circular arcs whose centers of curvature are O_1 and O_2. For simplicity O_1 and O_2 may be considered fixed points, O_1A_1 and O_2A_2 being rigid links. As the links O_1A_1 and O_2A_2 turn in a clockwise direction, the point attached to the link A_1A_2 and which momentarily coincides with the instantaneous center I follows a definite path. The velocity components of that point, respectively perpendicular to O_1I and O_2I, are

$$\left.\begin{aligned} V_{i1} &= V_{a1}\frac{O_1I}{O_1A_1} = \omega\frac{I_1A \times O_1I}{O_1A_1} \\ V_{i2} &= V_{a2}\frac{O_2I}{O_2A_2} = \omega\frac{IA_2 \times O_2I}{O_2A_2} \end{aligned}\right\} \qquad \text{.................. (1)}$$

where $\omega = V_{a_1}/IA_1$ is the angular velocity of the link. The velocity, V_i, of the point I is the vector defined by two projections as shown in *Fig.* 1.

Instantaneous center of inflexion, by definition, has veloc-

ity equal and parallel to V_i but is located in the link, which rotates about I. The distance from I to the instantaneous center of inflexion, J_0, is therefore equal to V_i/ω. The point J_0 may be located by working again with the components. Thus, referring to *Fig.* 1,

$$\left.\begin{aligned} IJ_1&=\frac{V_{i1}}{\omega}=\frac{IA_1\times O_1I}{O_1A_1} \\ IJ_2&=\frac{V_{i2}}{\omega}=\frac{IA_2\times O_2I}{O_2A_2} \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where values of V_{i_1} and V_{i_2} are taken from Equation 1. The point J_0, found by elevating perpendiculars to IO_1 and IO_2 from J_1 and J_2, is the point required. This is obvious from the fact that figures $IJ_1J_0J_2$ and the vector polygon involving V_{i_2}, V_i and V_{i_1} are similar and result from one another by a rotation equal to a right angle. Thus $IJ_0=V_i/\omega$, and the velocity of J_0 is $IJ_0\times\omega=V_i$.

For practical computations it is simpler to locate J_1 and J_2 from A_1 and A_2. For this purpose Equation 2 may be rearranged as follows:

$$\frac{IJ_1}{O_1I}=\frac{IA_1}{O_1A_1}=\frac{IJ_1-IA_1}{O_1I-O_1A_1}=\frac{A_1J_1}{IA_1}$$

$$\therefore A_1J_1=\frac{IA_1^2}{O_1A_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Similarly

$$A_2J_2=\frac{IA_2^2}{O_2J_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

It is to be noted that J_1 and O_1 are on the same side of A_1, and J_2 and O_2 are on the same side of A_2.

The circle having IJ_0 for diameter is called the circle of inflexion because the center of curvature of the trajectory of any point on that circle is at infinity. This fact can be established by noting that if J_1 and A_1 coincide, it is necessary from Equation 3 that A_1O_1 be infinite except in the special case where A_1 and I coincide. Thus if a point is on the circle of inflexion, the curvature of its trajectory at that point is zero, which justifies the name of circle of inflexion.

From knowledge of the circle of inflexion the center of curvature of the trajectory of any point A on the link can be defined by using Equation 3 which, when OA is unknown, can be written

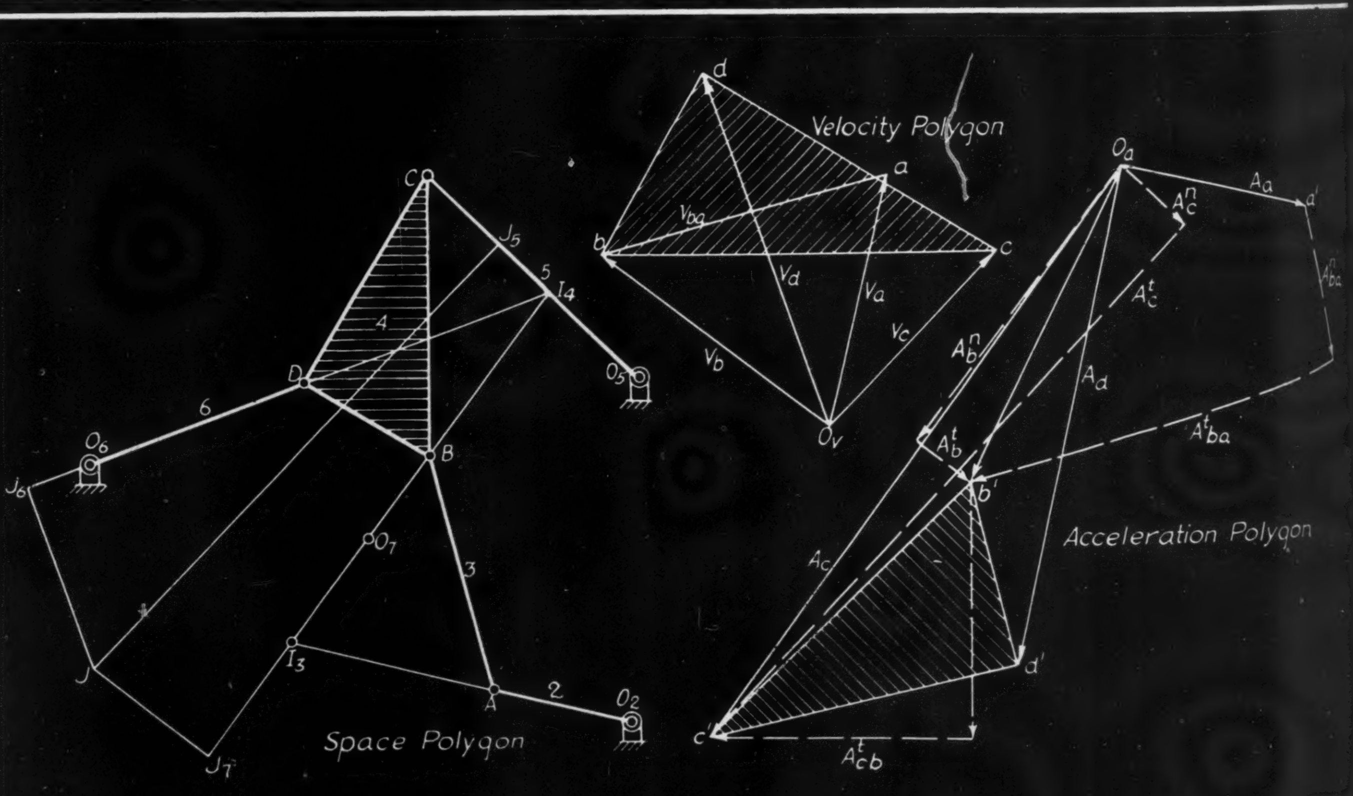
$$OA=\frac{(IA)^2}{AJ} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Thus since J is defined as the projection of J_0 on OAI, the point O is determined.

Equation 5 readily defines the projection on the normal to a trajectory of the center of inflexion if the radius of curvature of the trajectory is known, or the radius of curvature of a trajectory when the circle of inflexion is known. When the radius of curvature of the trajectory of a point is known, its normal acceleration, V^2/R, is defined when its velocity is known.

These properties will be applied to a problem involving floating links, that is, links the trajectories of which are not directly known. The methods can be compared

Fig. 2—With centers of curvature of trajectories for floating link 4 known, acceleration analysis is much simplified



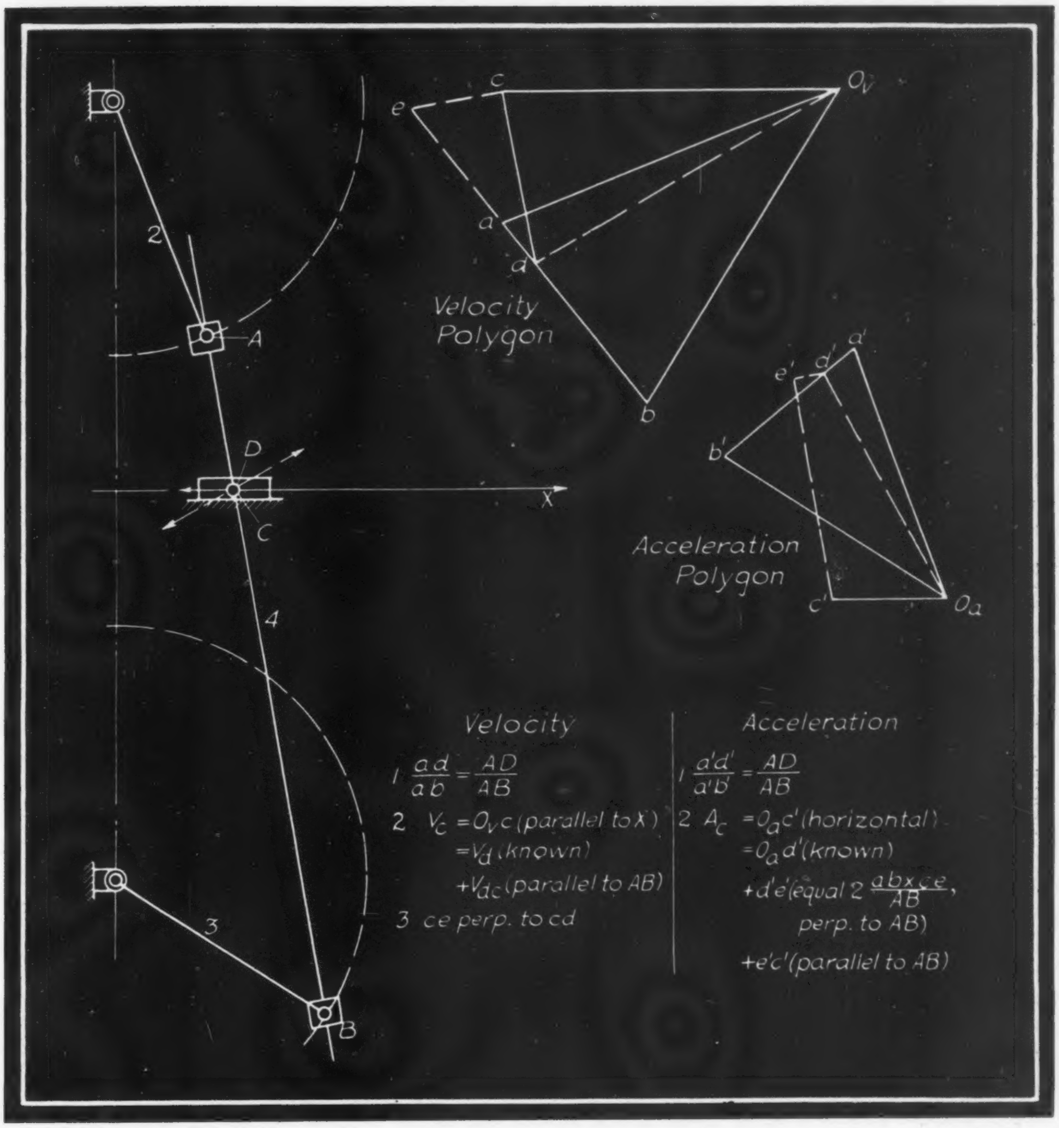


Fig. 3—Location of auxiliary point at D facilitates the solution of velocity and acceleration in this double slider-crank, conveyor drive

with those presented in a recent article by A. S. Hall and E. S. Ault*, the same mechanism being used for comparison. It is to be noted that in the article referred to the links 4 of *Figs.* 2 and 3 are called floating links. Actually, since these links have two points (for example, *C* and *D*, in *Fig.* 2) the movements of which are directly given, this designation is erroneous. The floating link is the link 3, and because the movement of *B* in 3 cannot be predicted from the movement of *A*, the direct analysis, *when the motion of A is given*, is impossible.

On *Fig.* 2, the motion of *A* is assumed to be given (uniform rotation); *BCD* is a solid link, the points *C* and *D* of which rotate around O_5 and O_6; and *AB* is a link through which the motion is imparted to *BCD*. The instantaneous center of rotation I_4 of link 4 (*BCD*) is at the intersection of the normals O_6D and O_5C to the trajectories of *D* and *C*. This defines the normal BI_4 to the trajectory of *B*, and in turn defines the instantaneous center of rotation I_3 of *AB*, which is at the intersection of I_4B and AO_2. The velocity diagram is self-explanatory. When the direction of the velocity of *B*, perpendicular to I_3I_4, is defined, the value of V_b is determined, since it is the value of the vector limited by the intersection with the perpendicular to *AB* drawn through the end of V_a. Thus the point *b* on the velocity diagram is determined and, operating in the same manner, the velocities of *C* and *D* are determined: O_vc and O_vd are normal to O_5C and O_6D respectively, *bc* and *bd* are normal to *BC* and *BD* respectively.

Instantaneous centers of rotation being known, the center of inflexion of link 4 can be determined. With

$$DJ_6 = \frac{(DI_4)^2}{DO_6}; \quad CJ_5 = \frac{(CI_4)^2}{CO_5}$$

calculated, the perpendiculars to I_4O_6 and I_4O_5 at J_6 and J_5 define the point *J*, center of inflexion, the projection of which on I_4B defines a point of inflexion J_7. Then the center of curvature of the trajectory of *B* is O_7, calculated from the relation

$$BO_7 = \frac{(BI_4)^2}{BJ_7}$$

Knowing this center of curvature, a straightforward analysis determines the accelerations of all the points. The acceleration of *A* is A_a directed along AO_2 (uniform

*"Auxiliary Points Aid Acceleration Analysis"—A. S. Hall and E. S. Ault, MACHINE DESIGN, Nov. 1943.

rotation) and is equal to V_a^2/O_2A. This acceleration vector is represented by $O_a a'$. Then the acceleration A_b is defined by:

$$\begin{aligned} A_b &= A^n_b + A^t_b \\ &= A_a + A^n_{ba} + A^t_{ba} \end{aligned}$$

Knowing A^n_b $(=V_b^2/O_7B)$, A_a and A^n_{ba} $(=V_{ba}^2/AB)$ in value and direction, the normals at the extremities of A^n_b and $(A_a+A^n_{ba})$ intersect at a point b', such as $O_a b' = A_b$. The same construction can be repeated for c':

$$\begin{aligned} A_c &= A^n_c + A^t_c \\ &= A_b + A^n_{cb} + A^t_{cb} \end{aligned}$$

Knowing A^n_c $(=V_c^2/O_5C)$, A_b and A^n_{cb} $(=V_{cb}^2/BC)$ in value and direction, the normals at the extremities of A^n_c and $(A_b+A^n_{cb})$ intersect at point c', such as $O_a c' = A_c$. It is unnecessary to repeat the construction for d', since the figure *bcd* in the diagram of accelerations is similar to *BCD*. Having obtained the base $b'd'$, the triangle $b'c'd'$ can be determined by determining the angle between $b'c'$ and *BC*, and rotating *BD* and *CD* by equal angles, thus defining d'. $O_a d'$ is the acceleration of *D*.

Reducing Number of Auxiliary Points

The method thus developed avoids the use of auxiliary points and the useless overburdening of acceleration diagrams. A further example will show how to reduce to a minimum the number of auxiliary points, where such points are used.

On the shaker conveyor schematically represented on *Fig.* 3, the points *A* and *B* have the same uniform motion. Slider *C* has a reciprocating motion, and the link 4, hinged on *C*, slides at *A* and *B* at the ends of the links 2 and 3. As auxiliary point the point *D*, which coincides with *C* at a given moment and moves on *AB* in such a manner that the ratio *DA/DB* is constant, will be selected.

From this definition it is obvious that the velocity vectors of *A*, *B* and *D* have their extremities on one straight line, since the difference of the velocities are proportional, which means that they have the same direction. Thus $O_v a$, $O_v b$ being the velocities of *A* and *B*, the point *d* representing the velocity of *D* is obtained by dividing *ab* in the same ratio as *D* (*C*) divides *AB*, or $ad/ab = AD/AB$. The relative motion of *C* with reference to *D* is along *AB* and the absolute motion of *C* is along the given direction *X*. Thus, drawing through *d* the parallel to *AB* and through O_v the parallel to *X*, the velocity $O_v c$ of *C* is obtained.

The acceleration diagram is as readily obtained: The acceleration of *D* is obtained in the same manner as the velocity (that is, $a'd'/a'b' = AD/AB$). The acceleration of *C* is directed along *X*, and is equal to the acceleration of *D* plus a tangential acceleration along *AB* and Coriolis acceleration $2\omega_4 V_{dc}$ which can be expressed as:

$$d'e' = 2\frac{V_{ab}}{AB}V_{dc} = \frac{2ab \times ce}{AB}$$

ab and *ce* are measured on the velocity diagram. This defines a point e' on the acceleration diagram ($d'e'$ is perpendicular to *AB*), and the point c' is at the intersection of the parallel to *AB* drawn from e' and the parallel to *X* drawn from O_a.

Thus it appears that with a judicious choice of an auxiliary point, the amount of work involved in an acceleration analysis can be reduced in considerable proportion.

Helicopter Bus Design Proposed

BUS lines all over the country recognize the essential similarity of their present service and that which the special flight characteristics of the helicopter render possible in augmenting or supplementing their traffic. The helicopter's business is precisely that kind of transportation—of persons and light luggage on moderately short hauls.

Based upon previous successful operations, an intermediate size of helicopter was proposed at a recent hearing before the Pennsylvania Public Utilities commission in behalf of a bus line serving western Pennsylvania, New York and part of Ohio. It was urged that a 6600-pound helicopter, using a 55-foot diameter rotor with a 550-600 horsepower motor and carrying a total of seven paid passengers and pilot, represented a practical size readily attainable in the state of present knowledge with a minimum of further experimentation.

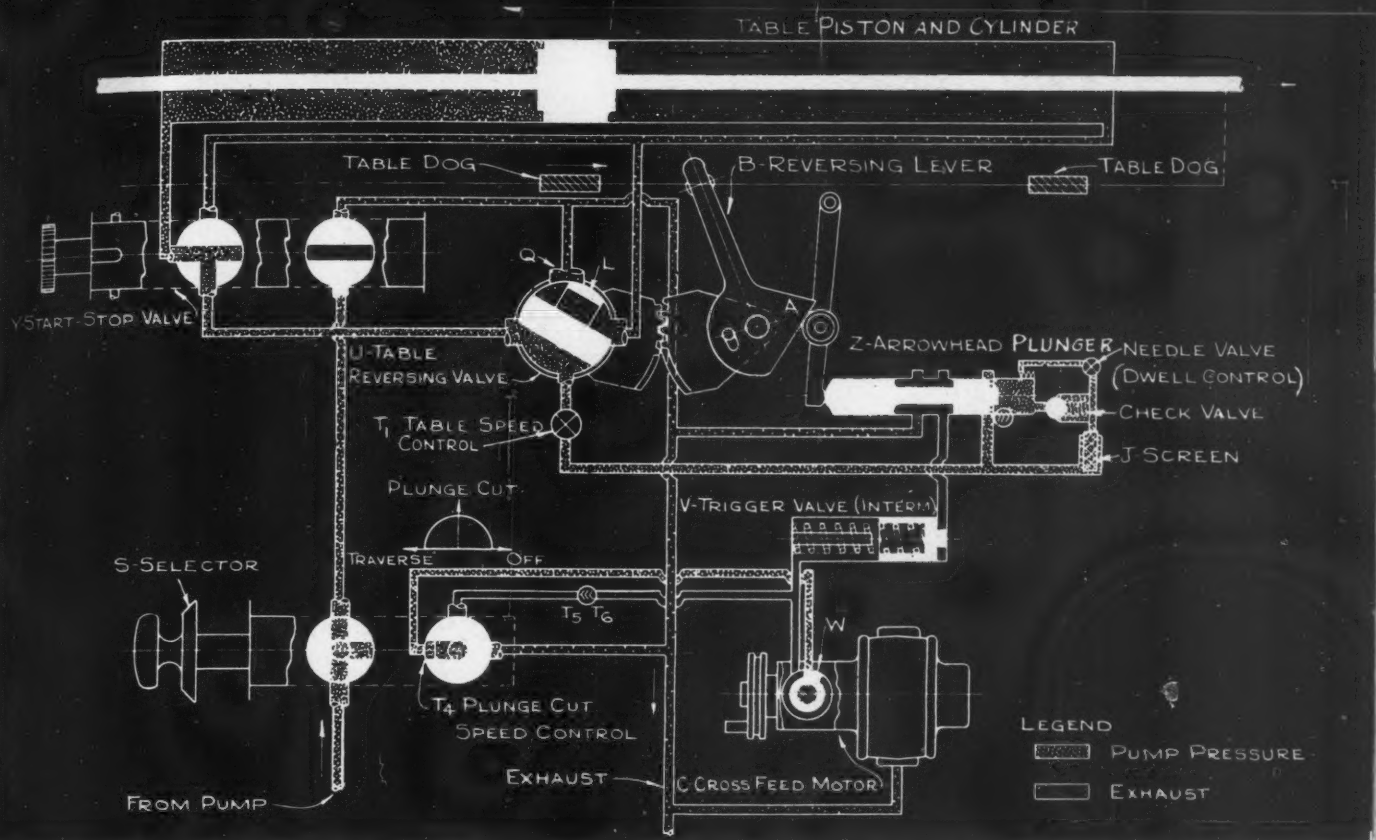
Short Runs Require Limited Fuel Capacity

An approximate price of $40,000 per unit of equipment was taken. This equipment would be depreciated over a five-year period, or 20 per cent, which is the current procedure of most airlines. These operations would require a fleet of eight airbuses with two in reserve, flying routes aggregating 2500 miles daily. Since the hops average between 25 and 40 miles and the longest overall run is approximately 200 miles, a limited tankage of 80 gallons of gas is allowed, 10 gallons of oil, 200 pounds of baggage and 200 pounds of mail and express.

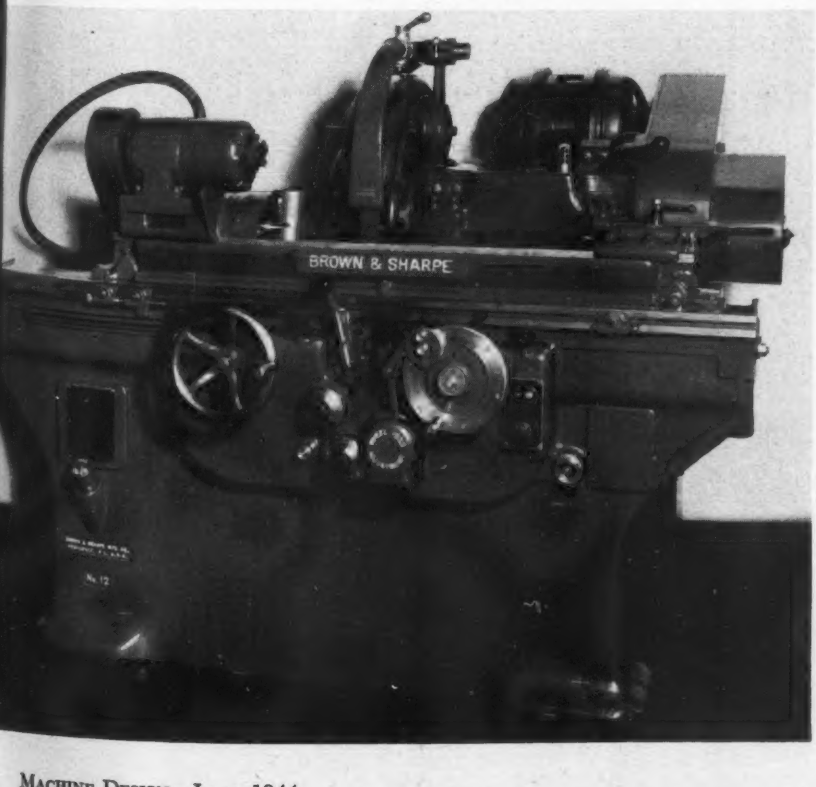
Power loading, based upon 550 horsepower, will be 12 pounds per horsepower. The disk loading, based upon the 55-foot rotor with an area of 2375 square feet, will be about 2.7 pounds per square feet, which experience has indicated would be adequate to insure safe landings at low speed.

A general analysis of operating costs results in a proposed cost of operation of about 38 cents per mile. With an anticipated 80 per cent load factor throughout the entire operation, due to the highly specialized service and the potential demand for such service in this area, a fare of 7 cents per mile is proposed.

In all of the interest aroused by this recommendation, which is of purely business and commercial concern as distinguished from personal sport and pleasure, we have a persistent pressure for new and added means as an adjunct to existing means of air and ground transport. From this we can reason that the need is surely there and the practical helicopter will, therefore, quickly result.—*From a paper by Agnew E. Larsen, Rota Wings Inc., presented at an S.A.E. section meeting in Wichita, Kans.*



Applying Valves in Modern Machine Hydraulics



By Richard K. Lotz

IN THE development of intricate hydraulic systems, particularly those of the interlocking type, it is of primary importance to consider each valve, not as an individual or separate unit, but rather as an integral part of the overall system.

The influence which any given valve can exert on the performance of others should be checked carefully throughout the planning of the complete system. One of the important considerations

Fig. 1—Top—Modified servo principle is employed to effect gradual automatic stopping and starting of grinder table

Fig. 2—Left—All hydraulic components of this modern plain grinder are fully enclosed within housing of the machine

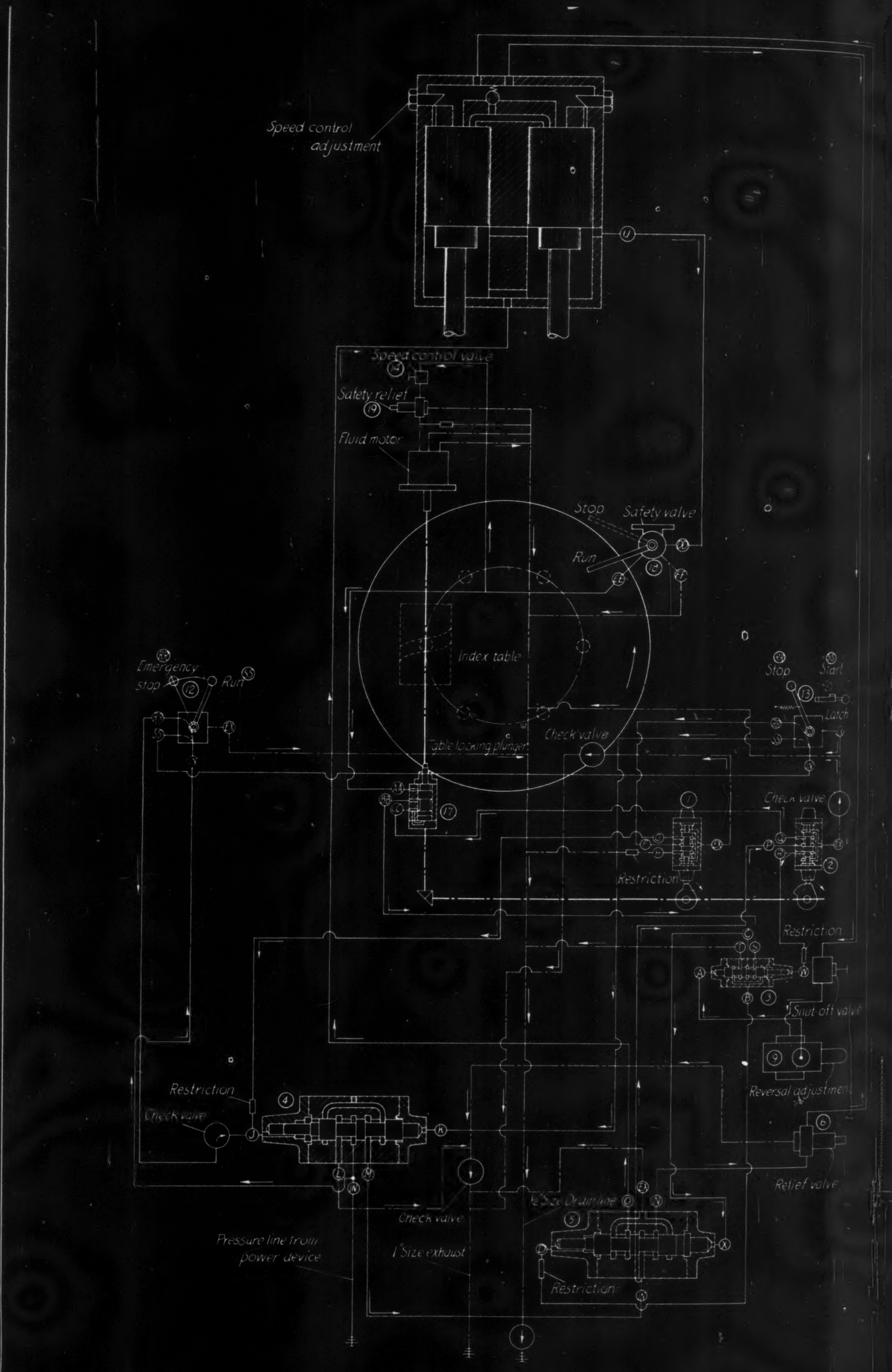
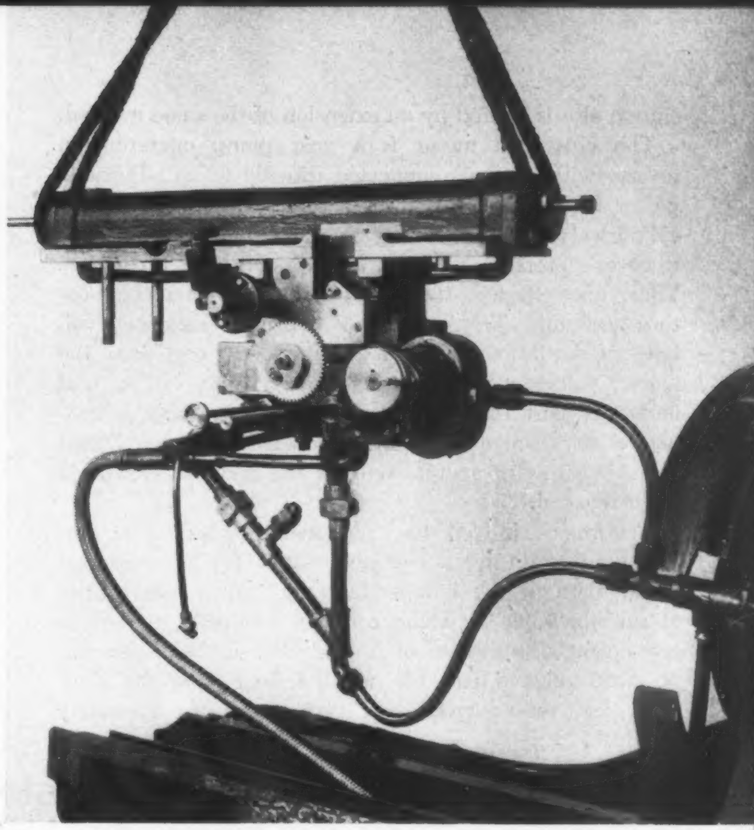

Speed control adjustment
Speed control valve
Safety relief
Fluid motor
Stop
Safety valve
Run
Index table
Emergency stop
Run
Stop
Start
Latch
Check valve
Table locking plunger
Check valve
Restriction
Restriction
Shut off valve
Reversal adjustment
Restriction
Check valve
Relief valve
Size Drain line
Check valve
Pressure line from power device
1" Size exhaust
Restriction

Fig. 3—Left—Circuit diagram of hydraulic shell-loading press. Judicious use of pilot-operated four-way valves makes automatic sequencing possible

Fig. 4—Right—Hydraulic control unit of the grinder shown in Fig. 2 ready for assembly into machine



likely to be overlooked in the design of a hydraulic circuit is the necessity for providing a path for exhaust oil from valves. A typical example of where this consideration comes into account is in the case of a pilot operated four-way (selector) valve. Here, pressures are fed at timed intervals, first to the piloting chamber at one end of the valve and then to the piloting chamber at the other end, and a path for release of pressure must be provided at the end opposite the one receiving the piloting pressure. Since oil is for all practical purposes incompressible, the valve spool or piston will not move if the line leading from the pilot chamber opposite the pressure side is blocked.

To demonstrate the proper utilization of all types of hydraulic valves, the most practical procedure probably will be to discuss the "whys" and "wherefores" of their application in systems representative of the latest in modern design.

An interesting circuit is that pictured in *Fig.* 1. This system is used on Brown & Sharpe's Nos. 10 and 12 plain grinding machines, where, to obtain maximum precision of control for feeds and reversals, low pressures and relatively large volumes are employed. Indicative of the current trend in machine hydraulics, all pumps, valves and piping are entirely enclosed within the machine.

Precision requirements for the control of traverse and cross feeds in a cylindrical grinder are of a high order. Such precision in this case is accomplished in a direct and simple manner by appropriate use of hydraulic valves working in conjunction with mechanical control.

Since it is necessary to be able to traverse the grinder table automatically or by hand, the rotary "start-stop" valve *Y* is used either to connect the table-feed cylinder to the control valves or short-circuit it into pressure and exhaust to permit hand feed.

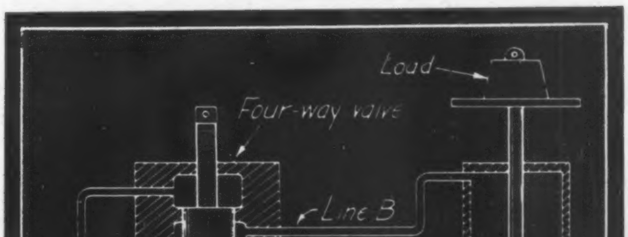
Employs Modified Servo

When the table is being traversed automatically, it is desirable to stop and start it at reversal at a gradual rate rather than abruptly. This has been accomplished through the use of a modified servo principle. Table reversing valve *U* is of the four-way rotary type, constructed with a land *L* that moves across the return port *Q* which is a shaped orifice, eclipsing it to give cutoff. This land is wider than the port so that while it is covering the port, the work table must be at rest.

Reversing lever *B* connects to reversing valve *U* through an arrowhead and lost-motion mechanism of well known type. Thus, when the table dog contacts lever *B*, valve *U* begins to close. The farther the table moves, the greater will be the closure of land *L* over orifice *Q* and progressively slower will be the table speed until finally it shuts itself off, always at precisely the same point. This permits grinding up to a shoulder on the work piece with complete assurance. The rate of retard may be controlled by the shape of orifice *Q*, making it simple to achieve smooth, shockless stop of the heavy work table.

Dwell at the end of the table stroke is accomplished by controlling the time required for land *L* to move across the covered port *Q* as follows: Arrowhead *A* is "fired" by a plunger urged by hydraulic pressure. A range of hydraulic resistance in series with a needle valve (which constitutes the dwell throttle) governs the rate at which the plunger moves outward and thus the rate of movement of land *L* past dead center. Accel-

Fig. 5—Below—This arrangement will not hold loaded piston without drifting because oil seeps past valve spool



eration also is limited by an extension of the same method.

The cross-feed motor is a gear pump operating in reverse with its shaft connected directly to an adjustable picker feed. On the shaft is a rotary valve *W* within a cylindrical chamber leading to the motor and arranged to cover a pressure inlet port at one point in its revolution. Thus, once started, the motor will make one complete turn and stop. Trigger valve *V* delivers a measured volume of liquid through an independent port into the motor, sufficient to move the rotary valve off its seat and thus start the single revolution. This valve is connected to a valve built into arrowhead plunger *Z* and is made so as to operate only at the chosen moment of table reversal.

Continuous in-feed for "plunge-cut" grinding is provided by admitting a continuous flow to the cross-feed motor through the independent port under the control of selector valve S, which contains a throttle to provide conveniently any speed of in-feed desired. When in this position, valve *S* cuts off pressure fluid from the work table and reversing circuits, giving a necessary safety interlock.

No packing is used in either the cylinder units or the valves. Controlled clearances reduce leakage or slip to a negligible quantity and, with clean hydraulic oil, long, trouble-free life of the units is assured. In all cases, automatic lubrication of flat and *V*-ways is furnished from the low-pressure side of the hydraulic system through pressure regulating devices. Oil returning from the ways passes through gravity filters before re-entering the oil reservoir.

It is possible to develop a number of different hydraulic systems for accomplishing the same results. Reference to *Fig.* 3, which is the circuit diagram of a shell-loading press developed by Logansport Machine, Inc., will show that the up and down linear motion of the rams might have been effected through the use of a rotary fluid motor in conjunction with a rack and pinion instead of with the piston and cylinder arrangement shown. Note also the work table drive. Six rollers on the underside of the work table progressively engage the groove of a cylindrical cam which is intermittently rotated by a rotary fluid motor. Conceivably this same action could

Fig. 6—Below—Combination of four-way valve and special two-way check valve permits automatic load holding

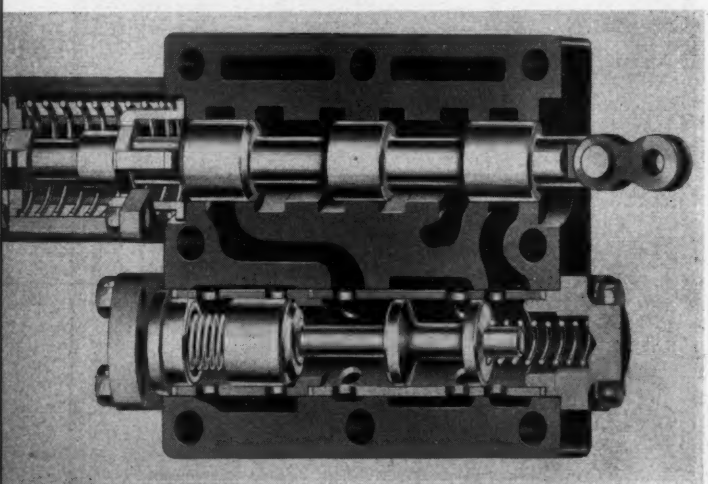
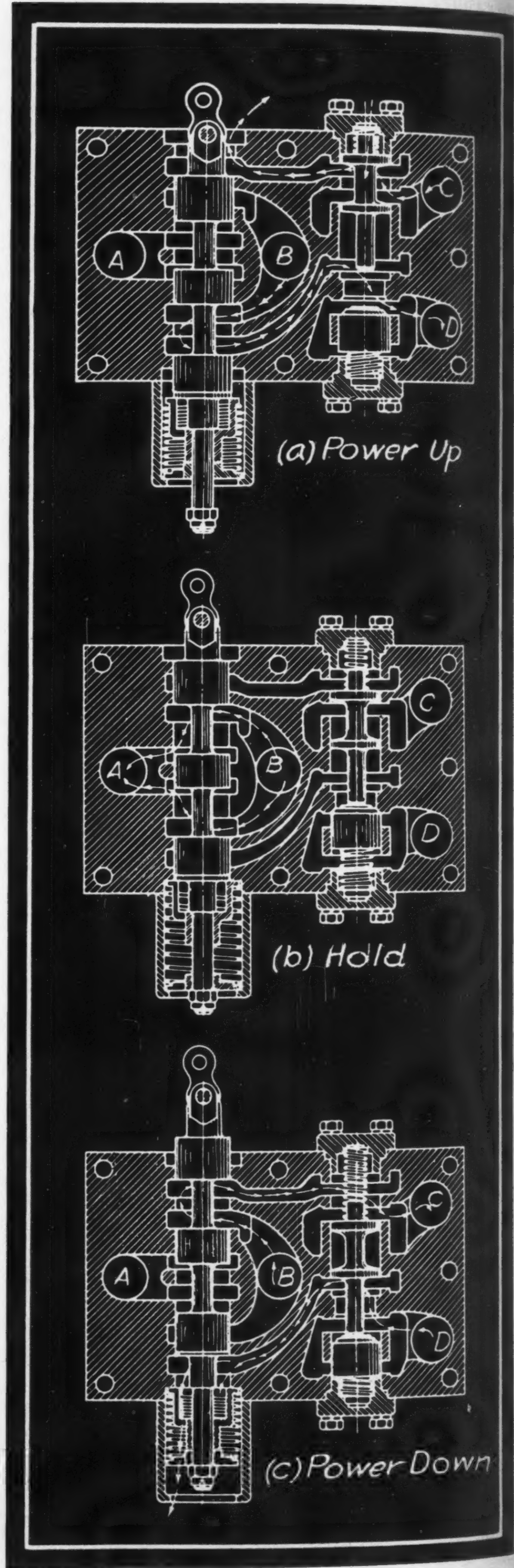
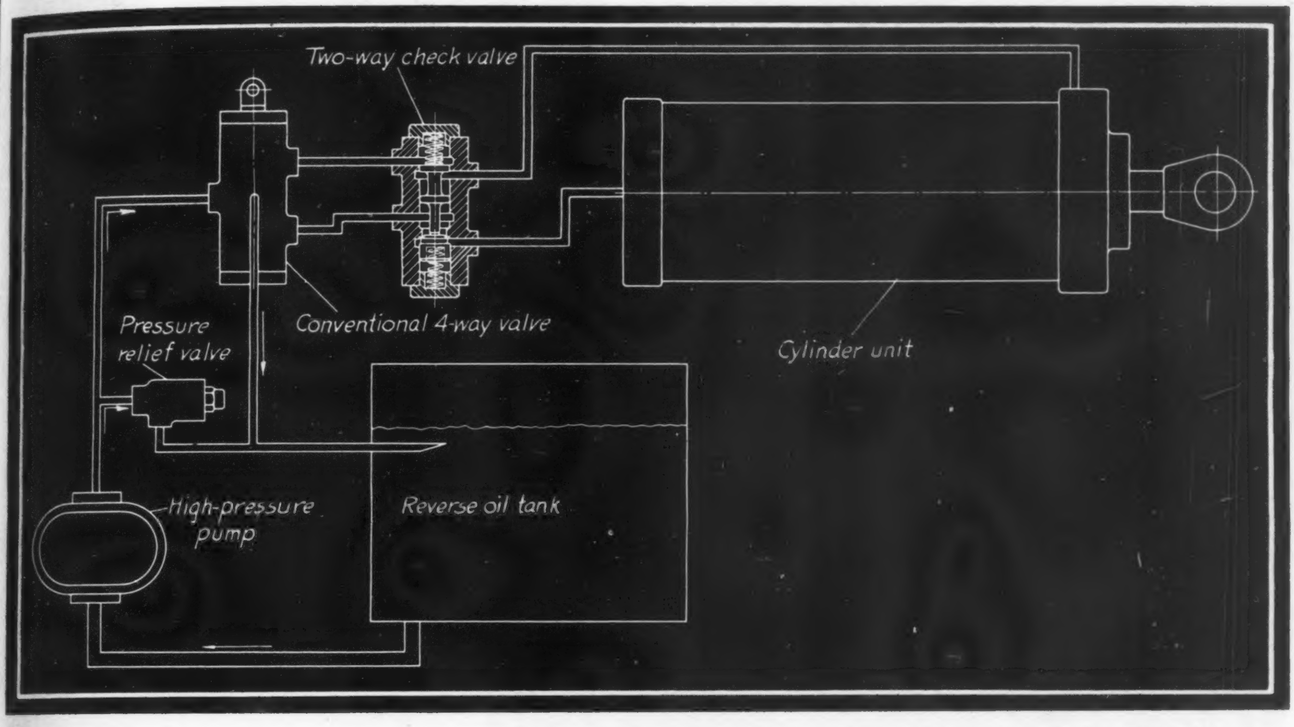


Fig. 7—Below—Showing how oil flows through combination unit pictured in Fig. 6 during the three operational cycles. Sealing is effected by conical-nosed tappet





be brought about by the proper utilization of a piston and cylinder with a rack and pinion drive working in conjunction with a one-way clutch.

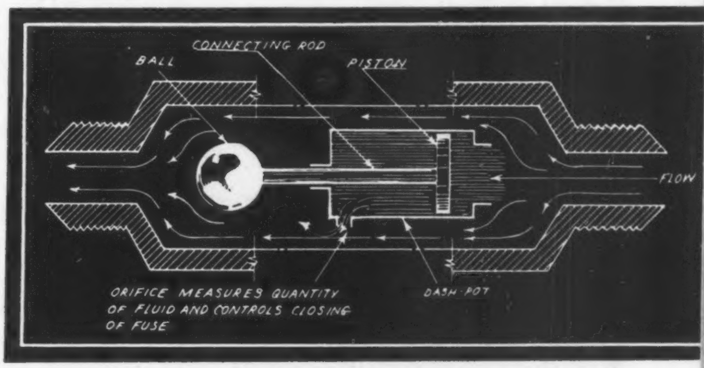
These or other alternative procedures were not used in this instance because, while they are entirely feasible, they would in all likelihood require an overall system more complex and more expensive than the system shown. Thus, in the development of hydraulic systems, as in the case of electrical, mechanical or pneumatic systems, the designer must evaluate the available methods on the basis of simplicity, efficiency and cost. Then too, if the equipment is for use on aircraft, the system must be designed with a severely critical eye cocked toward weight, size and vulnerability.

At first glance the circuit diagram pictured in *Fig.* 3 may appear extremely complex. However, like the diagram of a multistage radio, it can be broken down into less intricate units and components for detailed analysis. This particular system is of more than ordinary interest because it exemplifies "all-out" utilization of hydraulic controls with *mechanical* timing. Quite often it is more desirable to use electrical timing rather than mechanical and insofar as actual functioning is concerned, electrical limit switches working in conjunction with solenoid-actuated selector valves could have been used in this case. However, this shell-loading press handles highly explosive powder and, since there is always the danger of electrical equipment sparking, it could not be used.

In planning this system, the designer had at the outset, definite requirements as to what motions were to be effected hydraulically and in what sequence they were to occur. Thus, he knew for example, that the two rams would have to move up and down under power, in unison, and in interlocked cycles with the indexing of the work table. He knew also that the work table would have to rotate through one-sixth of a revolution each time the rams had reached the top of their stroke.

Fig. 8—Above—Circuit shows how standard four-way valve and two-way check valve can effect load holding

Fig. 9—Below—The hydraulic fuse combines check valve with metering dash pot to pass fixed amount of fluid



These timed motions of the rams and work table constituted the basic requirements. In addition, it was necessary to provide some kind of positive emergency stop which would cause all motions to cease abruptly at any point of any cycle, provide a means for running the rams and table through either a single complete cycle or continuously, and provide an arrangement which would stop all motions in the event a shell was placed improperly on the table. All these requirements were met through the use of standard commercial-type valves.

Pressurized fluid from the pump is fed first to the center port of a familiar type of pilot-operated four-way valve 4. Depending on the position of the valve spool, fluid will flow to either port *L* or *M*. Another line taps off the valve 4 intake and leads the pressure to the "in" port of a hand-operated four-way emergency valve 12.

With the emergency valve in its "run" position, pressure from its "in" port passes out through port *SS* to the "in" port of the hand-operated four-way valve 13, the function of which is to put the press through either only

one complete cycle ("stop" position), or to permit continuous operation (latched in "start" position).

To run the press, valve 13 is held in its "start" position, permitting pressure to pass through line *SS* to piloting chamber *K* of valve 4. This moves the spool of valve 4 to the left, pushing the oil from the piloting chamber at the left end of the spool through port *J*, in and out of valve 1 through ports *G* and *F* and through valve 13 to the exhaust line via ports *RR* and *EX*.

With the spool of valve 4 held in its "left" position, pressure from the pump passes through port *M* to the "in" port of pilot-operated four-way valve 5 from where it is tapped off to pass through valve 2 via ports *P* and *Q*. Both valves 1 and 2 are spring-loaded, four-way valves and when their cams are in the position shown in the diagram, the work table is stationary.

After passing through ports *P* and *Q* of valve 2, the pressure is led into port *CC* of cylinder 17, urging its piston end into engagement with one of six slots in the periphery of the work table.

Since the locking movement of the piston of unit 17 uncovers port *BB*, pressure passes through valve 3 via port *S* and *C* to the piloting chamber at the right-hand end of valve 5 through its port *X*. The spool of valve 5 is thus moved to its "left" position, pushing the oil from its left-hand piloting chambers through port *D*, through valve 3 by way of port *B* and to the common exhaust line through port *T*. By moving to its "left" position, the spool of valve 5 creates a path for pressure from the "in" port to port *N* and thence through the pressure-adjustment valve 6 to the top side of the rams.

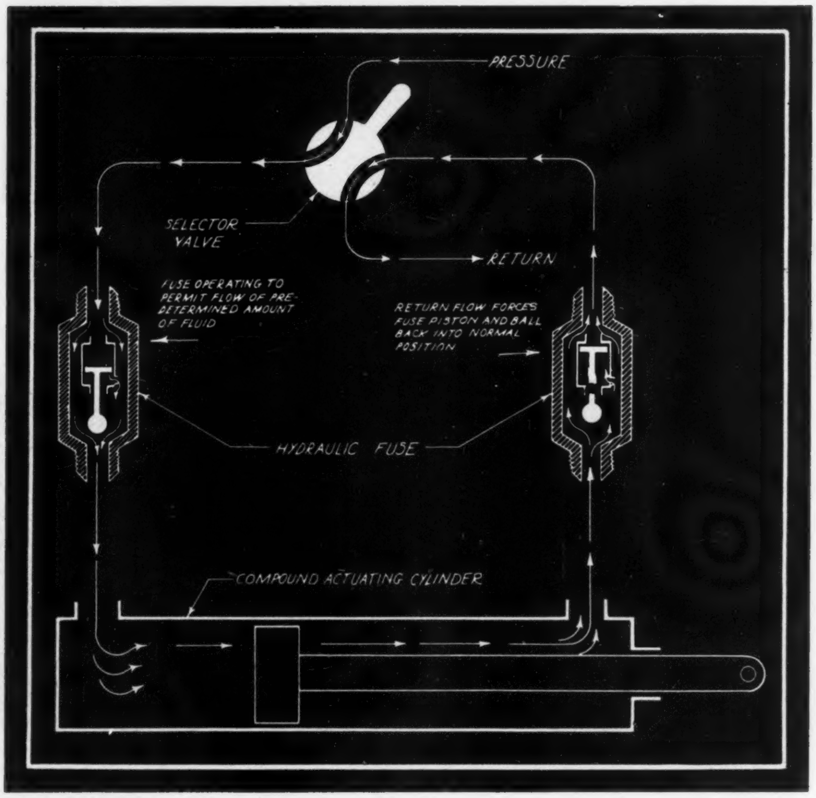


Fig. 10—Above—Installed as shown, the two hydraulic fuses guard against fluid loss in the event either of the lines between the selector valve and the cylinder are ruptured. Fuses should be as close as possible to valve

The rams, under the impetus of the pressure, will of course start moving down.

It probably will seem that appreciable time elapses from the throwing of valve 13 into its "start" position to the actual downward movement of the rams. Actually, all of the valve movements occur in a fraction of a second since the only movement of oil required through the control lines has been the small amount needed to move the valve spools.

Once the rams have started down, valve 13 can be either latched in its "start" position for continuous operation or thrown into its "stop" position for operation through only one cycle. If it is thrown into its "stop" position, pressure will pass through it via line *RR* and thence through valve 1 to drain via ports *F* and *H*. It will pass through port *H* rather than *G* because, at the beginning of the cycle when valve 13 was thrown into "start" the fluid motor drove all cams through a small portion of a turn, permitting the spring in valve 1 to push its spool into the down position. During this limited portion of a turn, a dwell in the table-indexing cylindrical cam permitted it to turn without attempting to drive the table against the locking plunger.

With valve 13 now in its "stop" position and the pressure it passes being led to exhaust through valve 1, there is nothing to prevent down and up motion of the rams, followed by the automatic indexing of the work table until the spool of valve 1 is once again pushed up by its cam.

Thus, the rams move to the end of their down stroke, the pressure being controlled by relief valve 6. When the pressure reaches its maximum, it is tapped off from the top of the cylinder to open sequence valve 9 and flows to pilot connection *A* of valve 3, moving the spool of the valve to the right. Pressure from the "in" port of valve 5 goes to port *P* of valve 2, the spool of which is still in the "up" position shown due to the dwell on its cam. (At this point, cams for both valves 1 and 2 are in the positions indicated by dotted lines.)

Pressure passes from port *P* to port *Q* of valve 2, on through ports *CC* and *BB* of unit 17 (locking plunger is engaged), to port *S* of valve 3 and from port *B* to pilot connection *D* of valve 5, moving its spool to the right. Pressurized oil now can flow through port *O* of valve 5 to the under side of the rams, moving them up.

When the rams reach the end of their up stroke, oil from the under side of the rams flows through two annular grooves in the rams, out of port *U*, through ports *DD* and *EE* of safety shutoff valve 18, and branches off to flow through speed-control 14 (a form of adjustable restrictor), through safety-relief valve 19, and on through the fluid motor which, by turning the cylindrical cam, drives the work table through one-sixth of a revolution.

(*continued on Page* 190)

Fig. 39—Hub of phenolic gear is cast-in metal insert to increase strength of part

By H. W. Gillett

War Metallurgy Committee

Part VII—Selection

Choosing the Right Material

WHEN the minds of the design engineer, the testing engineer, and the metallurgist meet on common ground—the designer willing to specify anything that is adequate without limiting the material to what was used before, the testing engineer ready to plan tests to evaluate adequacy for a specific purpose and the metallurgist disabused of the idea that data from standard tests are proof instead of just evidence—progress can be made. Each will then ask the other some embarrassing questions. The designer will outline the problem of selecting an alternative material or one of improved properties, for an existing part, by setting down complete information on service requirements, history of previous designs and materials tried, fabrication problems and facilities, etc.

What hitherto unused materials are proper candidates for consideration can be stated by the metallurgist once he is fully apprised of the real service conditions. Often he may be forced, however, to report that no known material has the combination of attributes that are properly demanded and that research to produce such an alloy will be long and costly with no certainty of ultimate success. As a stop-gap, pending the development of the unknown ideal material, he may well ask "Why not use the materials we've got, and engineer the necessary properties in by a judicious combination of materials?" This is a sensible question at any time, and particularly sensible now that there is a scarcity of many raw materials.

Conflicting requirements often lead to a search for a material with an unusual combination of attributes perhaps secured only, if at all, by the use of an excessive amount of strategic alloying elements. The engineering attack, putting materials together in such fashion that the needed attributes appear at the necessary locations, usually arrives at a better compromise than making the whole object of one material. Alclad duralumin, with corrosion-resistant pure aluminum on the outside and strong alloy on the inside, is an intelligent engineering compromise.

Instead of using a deep-hardening, highly-alloyed steel for a massive piece to take high tensile stress in a side bar of a chain link, several half-inch thick sections of carbon steel, side by side, might do the job. Irregular parts made in several sections and assembled by welding, copper brazing, or silver soldering, may allow putting a more

Concluding a series of articles abstracted from a War Metallurgy Committee report, beginning with the December issue.

wear-resistant section where it is needed. The head and shank of an exhaust valve operate at different temperatures and must resist different types of wear. Selecting each part for its own duty and welding them together may well be worth the extra operation of welding.

Often the interior of a part serves merely as a support, the exterior being the armor against corrosion, wear or fatigue. The principle involved in use of carburized parts for wear resistance can be applied with far greater speed of production through surface hardening by induction or flame-hardening methods. One might find cases where corrosion resistance on an irregular part is required in which pressing a skin of stainless steel to the desired outside dimensions, copper plating the inside, pressing into this "glove" a previously made "hand" of powder iron with high porosity and low weight, then copper brazing the glove on tightly would be much better engineering than hogging the piece out of solid stainless.

Bearings for freight cars are massive pieces of leaded bronze weighing about 25 pounds. When they are slightly worn on the wearing face, they go back for remelting. The bulk of the piece serves merely as support for the wearing face. Some two-thirds of the bronze can be replaced by malleable iron, with a vast reduction in the amount of bronze tied up in service. The composite, malleable iron plus bronze piece has the same dimensions as the all-bronze one, and is interchangeable with it.

Bushings or inserts cast into die castings or plastics, *Figs.* 39 and 40, malleable iron connectors for timber, hard facings for oilwell bits, expanded metal stiffeners for sheet steel for aircraft, the variety of "clad" metals that extend the old Sheffield plate idea into engineering as well as decorative purposes, are everyday examples of the cooperation of materials of different properties in providing a well-engineered whole.

Use of Clad Metals Is Expanding

Stainless-clad, nickel-clad, copper-clad steels and other combinations are commercial products whose utility was initially limited to those cases where a solid metal of the necessary surface properties was too weak. The necessity for conservation of strategic metals now alters the economic picture and the development of cladding processes, under the conservation urge, will lead to lower production cost.

In many cases the engineer has been deterred from layer construction by knowledge of the early high fabrication and assembly costs and by fear, in the case of clad and plated metals, of poor adherence. But improvements in welding, brazing, plating, etc., and the frequent opportunity to avoid much machining from large section stock are removing the basis for reluctance to use coated metals and built-up parts, *Fig.* 41.

Application of a surface coating by metal spray, *Fig.* 42, has a restricted, but real, utility. The production engineer often goes back to the design engineer with a suggestion for lowering production costs through such means, probably more often than the design engineer originally contemplates these means in the hope of putting particular engineering properties just where they are needed and calls in the production engineer to pass on feasibility. When both work together from the start with the aim of combining engineering properties, ease of production and conservation of strategic materials, as they are doing under the urge of war needs, they generally come out with "more, better, and cheaper", as is evidenced by some of the outstanding cases cited in "Tremendous Trifles"[1].

Engineering devices may be used to cut down the service requirements as to resistance to wear and corrosion. Among such devices are oil and air cleaners, likewise crankcase ventilators for the escape of water vapor produced in combustion of gasoline which, if not removed, becomes liquid water as the engine cools, and rusts parts on which it has condensed if they have been scraped clean or if the film upon them is pervious to moisture. Slushing compounds, the sealing up of aircraft engines and the provision of absorbents for removing moisture from infiltered air for protection in shipment are other engineering devices. The protection of mufflers and exhaust pipes

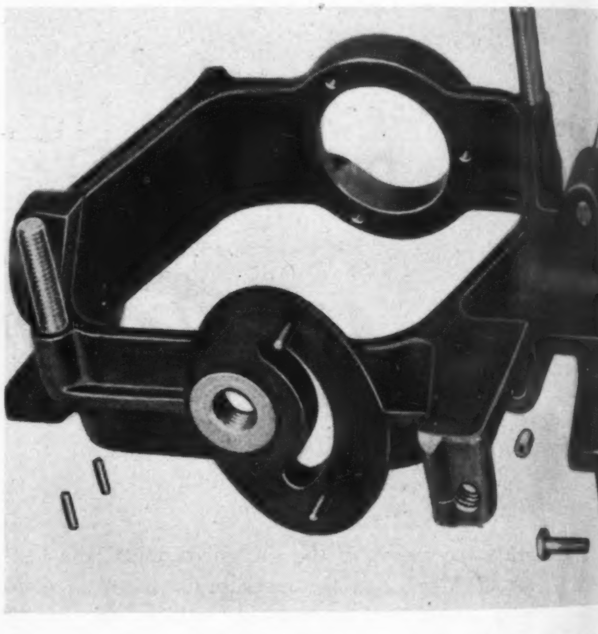


Fig. 40—Diecast magnesium part for automatic pilot utilizes threaded inserts to improve properties and reduce machining costs

from corrosion by water condensed from the products of combustion seems to await a commercial solution of the difficulty.

In the oil industry, chemical neutralization of acid liquors is widely applied to protect equipment with which the liquors come in contact.

Another engineering expedient is chemical passivation of steel, as by the use of sodium carbonate solution instead of water in cutting emulsions and in cooling water in general, or by use of chromate solutions, as is done to protect the boxes in which artificial ice is frozen and which are immersed in calcium chloride solution that would corrode them rapidly without the chromate addition.

In casting about for available materials that might be built into a composite structure or used alone, the metal-

[1] Army Ordnance, 1942.

lurgist is likely to bring up some old ones that have been relatively neglected by designers and some new ones just being developed.

Among the latter are the steels of increased hardenability due to use of boron-containing "finishing" additions, for which steels there are as yet no N.E. numbers. Certain heat-treatable aluminum alloys, containing a little zinc intentionally added and having a higher strength level than the standard ones, are on the horizon though they require the amassing of more data on behavior under conditions of corrosion and repeated stress.

That these alloys are only "on the horizon" in spite of the fact that they have long been known as "touchy" alloys, hard to control, and not beyond reproach as to behavior under corrosive conditions[2] is a good example of the importance of amenability to processing. Before 1927, such alloys were capable of giving 75,000 pounds per square inch tensile; now the strength can be brought to 85,000 to 90,000 pounds per square inch. But because of their sensitivity to slight variations in composition and heat treatment, the output of acceptable material of such an alloy from a given mill would probably be only a small fraction of the acceptable output from that mill of the better-understood and less touchy 24ST, prestretched and specially aged, with 70,000 to 75,000 pounds per square inch described by Jackman[3].

Moreover, it appears[4] that to make zinc and magnesium-containing alloys resistant to stress corrosion, it probably will be necessary to age them at such high temperatures as to end up weaker than the specially treated 24ST. All these difficulties might be overcome with sufficient experience, but rushing into production and use before they are solved is not good engineering. It may be good business to do intensive research in order to develop them ultimately into dependable engineering materials.

Possibilities for High Temperature Service

Magnesium alloys that can be used at higher temperatures than the present ones apparently can be developed by use of considerable amounts of cerium, and a sufficiently important use might warrant the cost and difficulty of producing the cerium.

For high temperature service of great severity, alloys containing cobalt, columbium, etc., in generous amounts offer highly interesting properties. Designers are seldom conversant with all these latent possibilities.

It is not suggested that while they are latent and insufficiently proved, the designer should specify them. Rather, by indicating his interest and pointing out his specific needs, he may accelerate many new developments, much as war needs and war scarcities have accelerated the development of the N.E. steels and the boron hardenability addition agents.

When a soldered joint is needed, the designer is prone to think in terms of the usual lead-tin solders, but has to seek exception from W.P.B. if he specifies more than 30 per cent tin in the solder. He may not be aware that solders containing little or no tin, from 1 to 4 per cent silver, and perhaps small amounts of other available alloying elements, have strengths superior to the lead-tin solder and have proved so usable that the word solder is likely, in the future, to connote an almost tin-free rather than a high-tin alloy.

It is easier to solder a surface that has previously been tinned than a bare steel surface. The advent of thin electroplated tin coatings on steel from which tin cans are made provides a solderable material for other engineering uses at a lower cost and with much less expenditure of tin than when only hot-dipped coatings were available.

Thick Lead Coatings Offer Protection

Scarcity of zinc for galvanizing is leading to the development of lead coatings, both hot-dipped and electroplated. It is becoming evident that, even though the lead coatings may not be entirely free from pores, the pores are not fatal in most uses, since the corrosion products soon plug up the pin holes and stop the attack. Too thin a coating may fail to hold the corrosion products in place. The relative softness of the lead is a drawback in some applications, but is not serious in others. Thus, lead coating, if used in sufficient thickness, serves as an acceptable substitute for galvanizing in a much wider range of use than the chemist or metallurgist of a few years ago would have been likely to anticipate.

Among established or proved materials well known to the metallurgist are high-strength cast iron, readily procurable at 45,000 pounds per square inch tensile strength, and if the need justifies, up to around 60,000, instead of the 20,000 to 30,000 that some design handbooks give.

When the previously satisfactory cast-iron valves for marine service prove unable to stand the shock of "near misses", the designer wishes for a shock-resistant cast iron, though he usually expresses this in terms of ductility rather than what he really wants. He neglects the fact that malleable cast iron already exists, and that "quick anneal", pearlitic irons, or possibly even cupola malleable, have toughness that at least makes them candidates for consideration[5].

Machinability Is Important Factor

When the designer has to pay attention to the demands of the production department for machinability, he may well consider these easily machinable malleable products, together with their stronger near relations, the Ford cast crankshaft and allied alloys, also the "graphitic steels" in which machinability and extreme wear resistance in some types of service are combined with mechanical properties of the general order of other heat-treatable steels. A similar combination of improved machinability without appreciable loss of mechanical properties is found in the carbon and alloy steels carrying small additions of lead.

Where strength is needed beyond that of ordinary normalized carbon or mild alloy steel, but quenching and tempering are not applicable because of the size of sec-

[2] *Light Metals and Alloys*, Bureau of Standards Circular No. 346, 1927.

[3] Jackman, K. R.—"Super-Aluminum Alloys for Aircraft Structures", *Aviation*, Aug. 1943.

[4] Muhlenbruck, A. and Siemann, H. J.—"Untersuchungen an Al-Zn-Mg-Knetlegierungen", *Luftfahrtforschung*, Vol. 19, Jan. 11, 1943.

[5] Compare "Substituting Malleable and High-Strength Iron (for Copper-Base Alloys)", *Canadian Metals and Metallurgical Industries*, May, 1943.

tion or complexity of the piece, the precipitation-hardened copper steels, carrying about 1 per cent copper, can be made to develop a yield strength of some 10,000 to 20,000 pounds per square inch above that of the usual normalizing steels. This improvement will penetrate to the core of heavy sections. A tendency toward selective oxidation of iron in preference to copper which tends toward surface checking in hot working is a drawback that may or may not be serious, depending on conditions.

Another way of getting above the strength level of normalized steel is by cold working. Cold-drawn shafting is well known to the designer, but there are neglected possibilities in carbon or mildly-alloyed, cold-rolled steel, rolled to conditions analogous to the "half-hard" and "three-quarter hard" states so often utilized in nonferrous alloys, in which formability sufficient for limited forming operations is retained and high yield strength is achieved. An interesting discussion is available[6] of the properties of cold-rolled low-carbon steel in thin sheet. While the work hardenability of ordinary steel sets limits of usable strengthening, the limits are greatly extended in the case of austenitic steels whose capacity for work hardening is much greater.

The most prominent member of this class is "18-8", the familiar austenitic stainless steel that usually contains very low carbon, about 18 per cent chromium and about 8 per cent nickel. This is valued chiefly for its well-known corrosion resistance and for the greater strength it shows at high temperatures (up to around 1000 degrees Fahr.) in comparison with ordinary steels, as well as for a high degree of cold formability.

The strength that can be imparted to 18-8 by cold work makes it of interest as an engineering material, even when no use need be made of its corrosion resistance or heat resistance. In normal times it has been considered for, and has found some slight use in, some of the "streamlined" railway passenger cars and experimental aircraft construction.

Manganese Is Promising Alloy

The strategic position of nickel and chromium makes such uses for 18-8 highly questionable from the point of view of conservation; hence, alternatives that do not exert such a drain on the supply strategic metals are of timely importance. Such an alternative appears to be attainable by recourse to manganese, which is produced in so great a tonnage that its use in austenitic steels is not out of the question.

In the soft condition, obtained by rapid cooling such as quenching from 1800 to 2100 degrees Fahr., 18-8 ranges from 75,000 to 95,000 pounds per square inch tensile according to the carbon content, which runs .05 to .20 per cent. The elongation and reduction of area in the soft state are high, 65 to 75 per cent. Yield strength in the soft state is low, only 20,000 to 30,000 pounds per square inch, but is rapidly raised on cold working.

By severe cold work, that is, in very light gages, the tensile can be raised to 300,000 and the yield to 250,000 with still a little ductility, say 1 per cent elongation and 3 per cent reduction of area. Intermediate conditions, for example, 185,000 tensile, 140,000 to 150,000 yield and 5 to 8 per cent elongation can, of course, be had.

The cold-worked strength is lost in welding. During cooling from the welding heat a carbide precipitation may occur that is detrimental to resistance against some types of corrosion and to high temperature behavior. Carbide stabilizers, such as titanium and columbium, are added to avoid this precipitation. Spot welding produces so small an area of softened material that the presence of the soft areas does not materially detract from the engineering performance of many spot-welded structures, but other types of welding are seldom applicable to strong, cold-worked austenitic alloys.

Stainless Has Noteworthy Fatigue Properties

The performance of cold-worked 18-8 in fatigue is noteworthy. The material hardens so rapidly by cold work that there is produced, at the base of a notch, a condition of so much enhanced strength that the notched-fatigue behavior is excellent. Indeed, in the fully soft condition the endurance limit on a polished bar is less than that of a similar bar carrying a notch, and the "damage" resistance also appears high.

After having been cold drawn to a tensile strength of 132,500 pounds per square inch, a polished endurance limit of 70,000 pounds per square inch has been found for 18-8, and a notched endurance limit of 50,000 pounds per square inch. Similar behavior under cold work to that of 18-8 is found in the manganese austenitic steels. Franks, Binder and Brown[7] report the following cold-worked properties for the compositions indicated:

Composition of Material					Properties		
C %	Mn %	Cu %	Ch %	Ni %	Tensile (psi)	Yield (psi)	Elongation (% in 2 in.)
.10	16.5	1	..	..	180,000 to 200,000	125,000 to 150,000	about 10
.23	16.5	0.7	3	3			
.23	16.5	1	3	3			

If corrosion resistance is required, a steel of .14 per cent carbon, 16 per cent manganese, 12 per cent chromium, is suggested by these authors who give its cold-worked properties as 190,000 to 215,000 tensile, 125,000 to 150,000 yield and 15 per cent elongation. The spot welding behavior of all these is said to be satisfactory. No data on fatigue-properties are reported, but the same general behavior as for 18-8 would be expected.

None of the austenitic steels machine as well as do ordinary steels, but small additions of sulphur, selenium, lead, bismuth, or silver are sometimes made to improve machinability with little detrimental effect upon mechanical properties. "Free-machining" 18-8 is an article of commerce. It might be expected that the low or high-carbon manganese stainless steels, by dint of small alloying additions and of special elements such as those previously listed might be brought to a degree of machinability or at least grindability that would adapt them to quantity production for a much wider range of engineering uses than those obtaining at present.

[6] Carnegie-Illinois Steel Corp.—*USS Air-ten Steels, Physical Properties and Welding Characteristics*, Dec. 1, 1942.

[7] Franks, R., Binder, W. O. and Brown, C. M.—"High Manganese Austenitic Steels", *Iron Age*, Oct. 1, 1942.

Because of the propensity for carbide precipitation in the temperature range 900 to 1400 degrees Fahr., the handling of any austenitic steel must be carried out with regard to the metallurgical factors involved. The whole story is lengthy and complicated with respect to securing suitable mechanical properties plus the acceptable welding behavior and immunity to specific chemical corrodents called for in the manifold uses in the chemical industry. It is not so complicated when mechanical strength only is involved, but the austenitic steels are different from ordinary steels and they have to be handled intelligently to avoid mistreatment in processing.

Articles may be made from iron powder by pressing, sintering, then finally finish machining or "coining" into final dimensions by pressure, if they do not come close enough to dimensions after sintering.

Use of the iron powder objects is being extended beyond bearings, other objects usually being made as dense and pore free as the method will allow. Small gears are made that require no finishing, and, though the usual

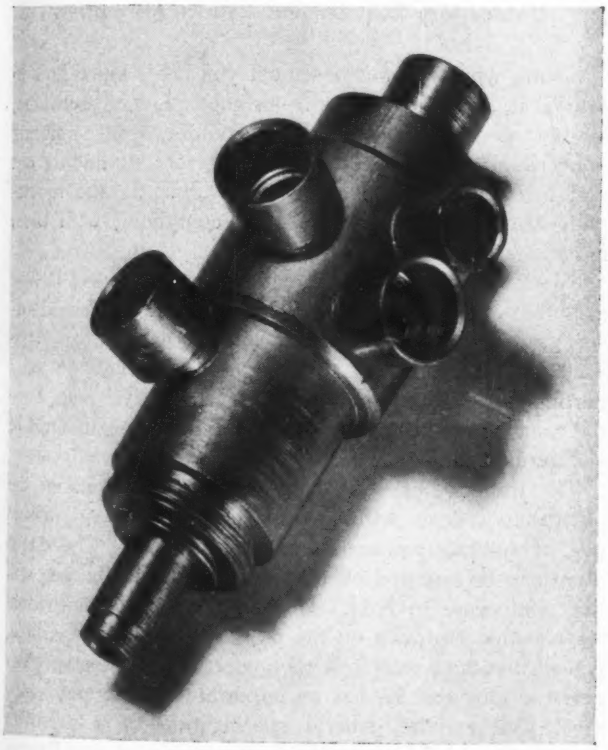


Fig. 41—Valve built-up with brazed parts, effecting an economical assembly otherwise difficult to produce

products are small since it is difficult to compact properly the inside of large pieces, the size is being extended as experience is gained[8].

Mechanical properties are not high. One tentative listing of properties expected gives three grades, one of 15,000 pounds per square inch tensile, with very little elongation, about ½ per cent; another of 25,000 pounds per square inch and 3 per cent; and a third of 35,000 and 7 per cent.

Thus, the properties range from approximately those of an extremely weak cast iron to approximately those of a weak malleable iron or of a weak zinc-base die casting. The virtues are not in strength as engineering materials, but in the low production costs when the production is large enough to amortize the dies and when the pieces come out accurate enough in dimensions to require no machining.

Substitute for Copper Band

A German substitution for the all-copper driving band for projectiles progressed in two stages: First, the employment of a duplex (half soft iron, half copper) band, with iron for the portion in the seating groove and copper for the projection beyond the groove, bonded to the iron; second, the utilization of a pressed-on powder-iron driving band, with the pores wax-impregnated to avoid rusting. Such bands are highly brittle against being pried off, but appear to resist sufficiently the forces applied in use.

In the first case, the traditional material is used, but only where its properties come into play. In the second, the properties demanded by service are supplied, and the fact that other properties, not called upon in service, are notably inferior, has not been allowed to prejudice the engineering selection.

New methods of fabrication are coming in, such as "coining" of gears cast nearly to shape, by pressing into a die that gives them their exact final form or an approach to this. Casting may replace forging, as is the case with the crankshaft of the German Jumo 211 B engine for the Heinkel and Junkers planes. The willingness of German designers to use a cast crankshaft in a high-power engine indicates that they have taken the lesson of the Ford crankshaft to heart. Conversely, welding together of rolled or forged pieces often replaces castings. There is continuous change in fabrication practices as the art advances.

In view of the many radical changes in fabrication methods the production engineer may well be called into conference with the design engineer, the testing engineer, and the metallurgist, so that the amenability of the candidates for consideration as alternative materials to new, convenient, methods of fabrication may be discussed along with the other features entering into a choice.

Process Can Spoil Best Material

It is also the task of the production engineer to guard the quality and uniformity of the product, by setting up suitable production control tests and records. A wrong process can spoil the best material. For example, perfectly good forging stock can be made into consistently bad forgings, so it is as necessary to control the forging process as it is to control the forging stock. The same holds for nearly all processes, since few processes are foolproof. It is axiomatic that there is need for process specifications, for indicating and recording instruments to catch variations that would otherwise go unnoticed, and for tests made and inspection exerted at suitable steps in the process so that trouble is caught before it is too late to do anything about it.

Design, choice of materials and processing are all inseparably connected. Each has to be done with an eye

[8] Frye, J. H.—"Powder Metallurgy", *Army Ordnance*, May, June, 1943.

to the others, and with engineering judgment directed toward the true conditions of service. There are aids to, but no substitute for, judgment in any of the three.

Handbooks and lists of alternatives can tabulate certain properties of well-known materials on the basis of average expectancy of properties determined by standard tests. It doesn't take an engineer to run an eye down such columns, or to pull the slide on a slide-rule type of steel "selector".

It does take engineering background and judgment to appraise the true requirements of service and to instruct the testing engineer what attributes to attempt to measure in quantitative figures, and the metallurgist as to what brand of metallurgical stability is demanded.

When the standard or simulated service test results are in and the metallurgical evidences needed have been adduced, there still remains the engineering responsibility of making a selection of, and writing sensible specifications for the permissible materials.

Once the desires of the buyer are expressed in a specification, the supplier has only to comply with the letter of the specification. If the buyer has not correctly stated his wants, or has not used the correct language in expressing them, he is not sure to get what he really needs. Hence the enterprising supplier does not rest content with an inquiry couched in terms of some standard specification, but sends a "sales engineer" to inquire what the particular intended use is so that he may supply what is adequate for the purpose.

Fig. 42—Bushings produced by metal spraying. Made on a mandrel, inside surface is high grade babbitt backed by metals having the properties desired

Material specifications are likely to be compromises. Different users state their knowledge, beliefs, and superstitions as to what they need, expressed in chemical composition or in terms of standard property tests. The producers object when the alleged requirements cannot be met, but are not concerned if the requirements can be met, even though they have no pertinence. The result is a specification describing the material in terms of chemistry and commonly determined properties without any footnotes pointing out that the prescribed chemistry is only a means to the end of obtaining the properties. Among the properties, one may be truly needed in a given type of service; the others are not necessary, but merely go along at some normal level together with the desired property.

Because of the sanctity of a specification once agreed upon between buyer and seller, there is a pseudo-sanctity about any officially promulgated specification. The existence of a set of chemical specifications for a class of products tends to bar production of other equally good or better products not conforming to the specifications.

Officially promulgated specifications do not allow savings through the use of modified compositions such as the uninhibited Germans employ. This tends to make the engineer, who looks up existing specifications in a handbook, phrase his bill of materials in terms of the existing chemical specifications instead of in terms of mechanical properties or by adding the phrase "or equivalent" to his listing. That the limited types of specifications do include acceptable materials should not blind us to the fact that they often exclude equally acceptable materials.

Unnecessary Requirements Restrict Alternatives

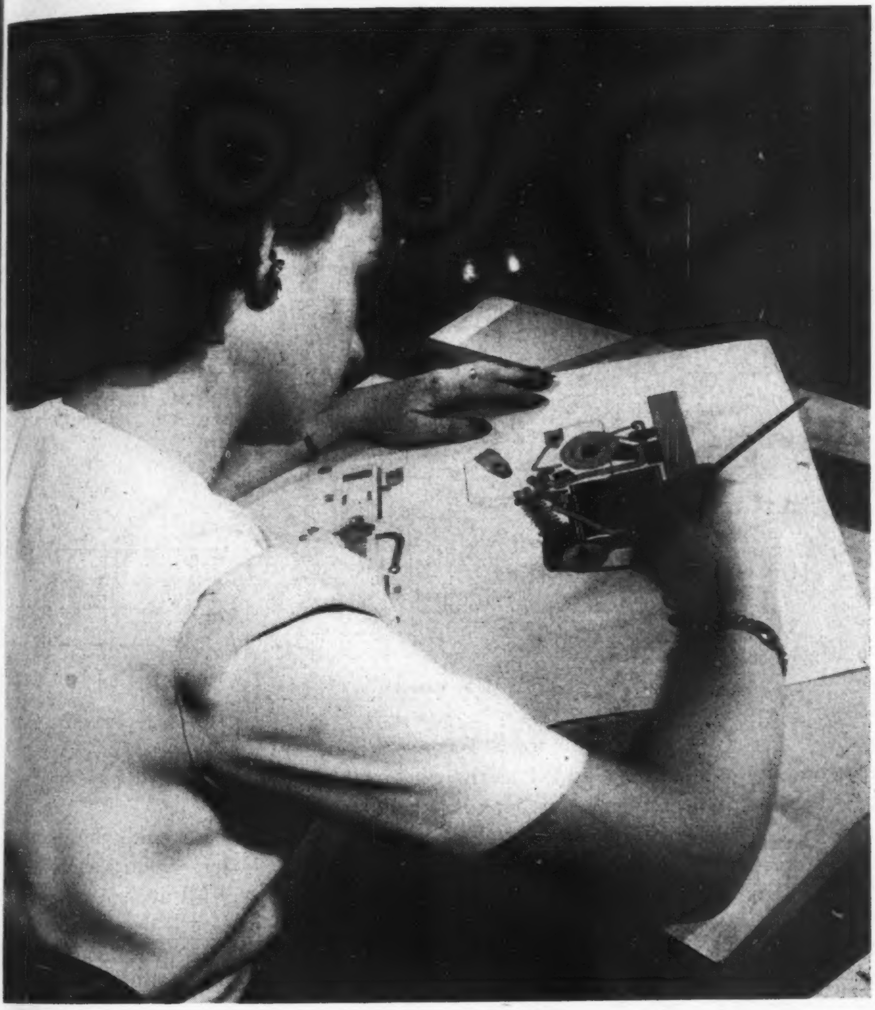
Saying what you mean—but if you don't know how to express it, not trying to say it—is good practice anywhere, doubly so in specifications. Refraining from imposing unnecessary requirements is as important as finding out and including those that are necessary. As the restrictions are added, the difficulty of complying with them multiplies.

There are two kinds of specifications, the word having a double and much too broad a meaning. A "standard" specification for one material which may be put to a thousand uses can only try to describe the squareness of a particular peg, and to insure that successive pegs have the same squareness. It's the *peg* that's being thought of and written about.

The design engineer's individual specification, on the other hand, deals with the *hole*. It seeks any suitable peg of suitable squareness to fit that hole. The edges often can be rounded off considerably before the peg will turn and cease to hold. However, when the individual specification is drawn on the peg rather than on the hole, it may become worse than the general one, if the specifier gets the idea that he has an important service and hence must jack up the general specification to a narrower chemical range and to a higher level of mechanical properties, or to require more alloy in the steel on the theory that since alloy costs money, the more there is, the better the steel must be! Too often the engineer, not familiar with metallurgy, asks for a high side of the chemical range, the high side of the strength range and, at the same time, the high side of the ductility range, not realizing that strength and ductility usually are inversely related. His attempts to sharpen the peg only make it more difficult for the supplier to provide any peg at all, and the sharp peg may be less useful to him than one with gently rounded edges.

One can easily sum up the principles of the selection, testing and specification of engineering metals. Good selection, good testing, and good specifications all try "to make the punishment fit the crime".

(End of Series)



Principal parts of this device are instantly recognizable as a result of simple shading

By H. E. Parks
Westinghouse Electric & Mfg. Co.
East Pittsburgh, Pa.

Shadowgraphs Simplify Pictorial Drafting

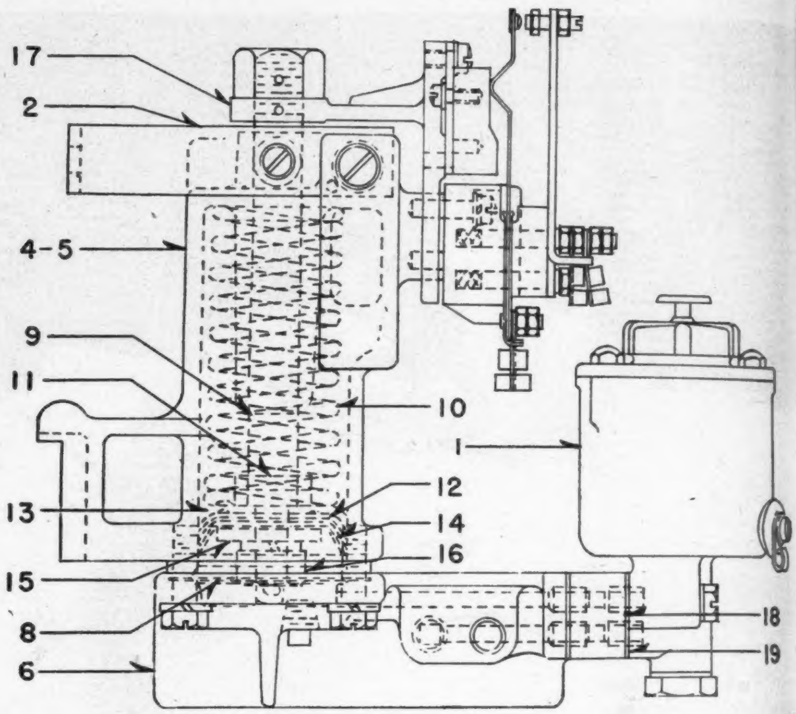
IMPORTANCE of pictorial drawings is greatly amplified when engineering instructions and data must be interpreted by inexperienced or partially-trained personnel. Such illustrations can be prepared in many ways depending upon the purpose of the data and the amount of money it is considered economical to spend. The cheapest method is to use line illustrations made from the assembly drawings of the apparatus. Photographs may be used but they have serious limitations. Recently, air-brushed isometric and perspective drawings have been employed extensively but they are expensive.

Line illustrations as in *Fig.* 1 are satisfactory but, in many instances, those who must use the data are not skilled in reading drawings. Consequently they have great difficulty in visualizing what the illustrations represent. For any engineering data prepared with this in mind something better than line illustrations must be used.

Photographic illustrations are expensive and require a great deal of time to prepare due to the necessity of either sending a photographer to the factory at just the right time to get assembly photographs or of carrying the apparatus to the photographic studio after it has been built. Air-brushed isometric or perspective drawings are even more expensive since they require many hours work by relatively high-priced artists or draftsmen.

A method has been developed to make a shaded illustration, *Fig.* 2, that is satisfactory for many purposes and cheaper than photographs or the still more expensive isometric or perspective drawings. These "Shadowgraph" illustrations can be prepared without the necessity of sending a photographer to the factory to find the assembly

Fig. 1—Line illustration of an air cylinder and magnet valve



and to photograph it or of requisitioning parts or assemblies from the factory. They can be made for apparatus that has been built and shipped many years ago or for apparatus that has been designed but not yet built. Concealed parts can be shown that could not be shown in a photograph unless a cutaway view is taken. Such illustrations can be prepared in less time and with less expensive personnel than that required to prepare perspectives.

Shading Depends on Method

Depending on whether a photostatic or photographic method is to be used to obtain the final illustration either blueprints or black-and-white prints of these drawings are obtained. If the photostatic process is used the blueprints are shaded with show-card colors. Starting with the main castings or the parts that would normally be farthest from the observer if he were looking at the actual assembly a shade of yellow-green is used. Adjacent parts are painted with two shades of orange-yellow using the shade that will produce the lightest parts on those nearest the observer. Judicious use of these shades will give the final product a photographic appearance. The continuity of a casting or part in an assembly can be shown by coloring it all one shade. Any lines, item numbers or parts that are not covered by the coloring are eliminated by covering them with red opaque. Any parts that are to be added can be drawn in with brush white and appropriately colored.

This colored print may be several times larger than the final picture. A photostat is then made of the colored blueprint reducing it to the required size. The original being negative the photostat will be positive. Due to the orthochromatic properties of photostat paper and by using a G filter the blue paper and red opaque will produce a fairly white background and the white lines will be sharp black. The three colors will be three shades of gray with the yellow-green producing the darkest shade. The parts farthest from the observer are the darkest, the nearer parts being lighter. Arrow lines and reference numbers are added to the photostat with India ink and the finished illustration is then ready for reproduction.

When a photographic method is to be used the black-and-white prints are shaded with three shades of warm-tone gray. Here again the farthest parts are shaded darker and the nearer parts lighter. All unnecessary lines and parts are removed with brush white. The reduction is determined and the drawing is photographed on a lantern slide plate.

Prints are then made from this negative with the picture enlarged to the size required. Arrow lines and reference numbers are added to this print and the finished picture is ready for reproduction.

Shadowgraphs present a new approach to the problems of engineering illustrations and semitechnical instructions. They combine the clarity of photographs with accuracy of line drawings and permit emphasizing any particular features.

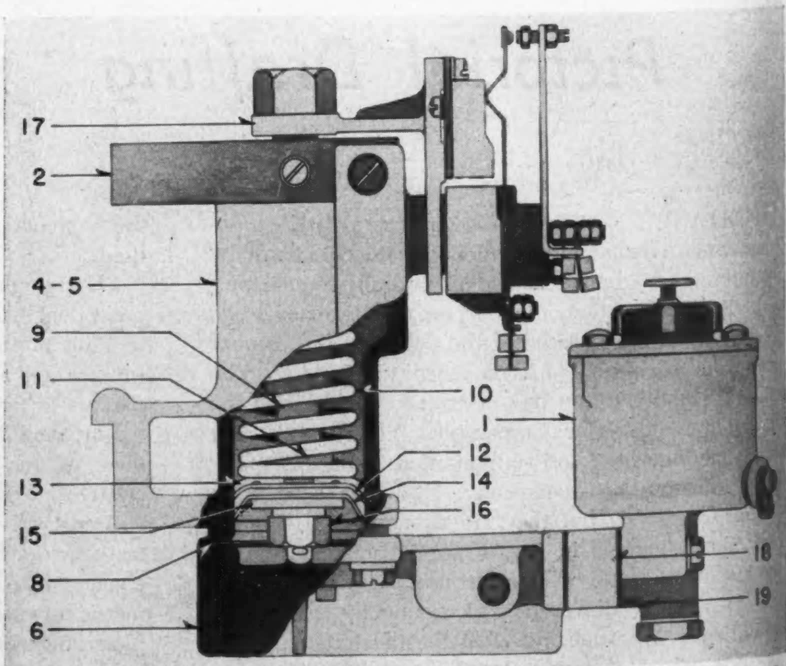


Fig. 2—Shadowgraph illustration of air cylinder and magnet valve prepared from line drawing shown in Fig. 1

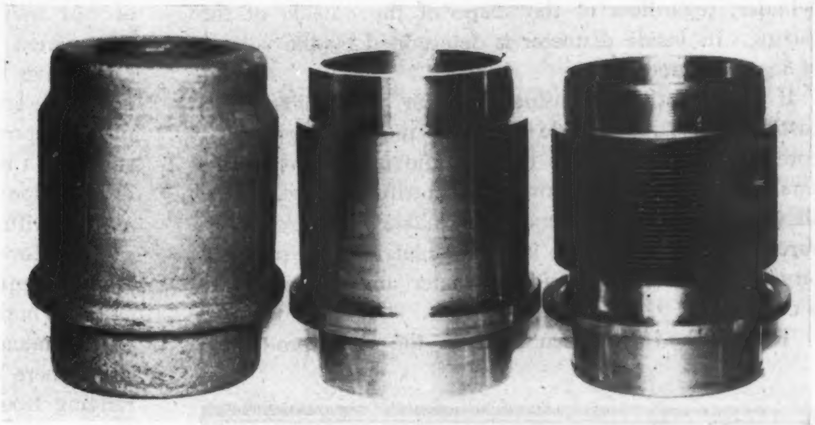


Fig. 1—Right—Cylinder barrel for radial air-cooled engine as centrifugally cast. Finished barrel is shown at extreme right

Utilizing the Centrifugal Casting Method

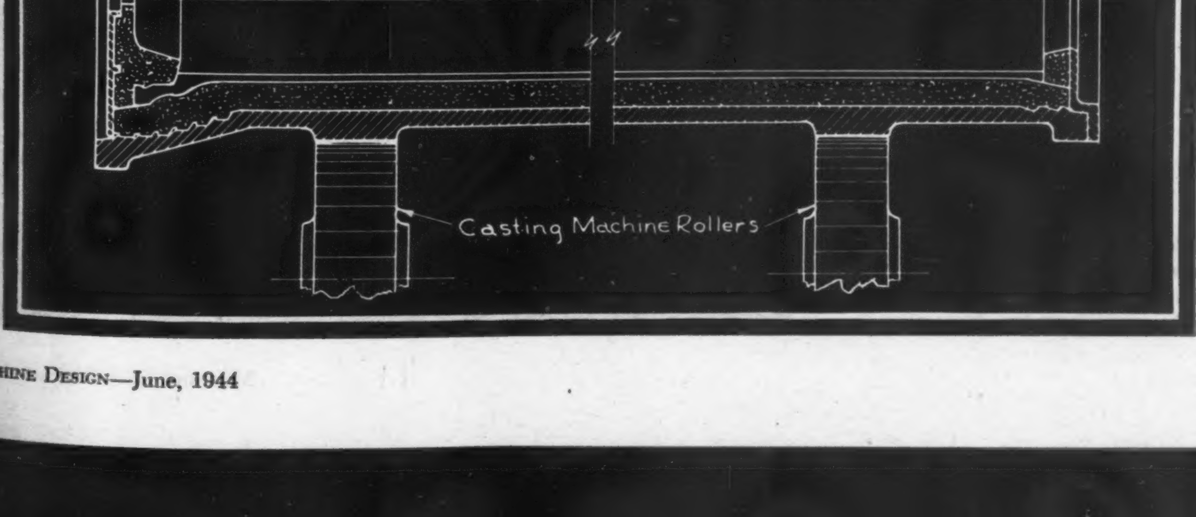
By S. D. Moxley
Chief Engineer
American Cast Iron Pipe Co.

CASTING of metals centrifugally is basically pressure casting. In static molding, feeding is done by atmospheric pressure and gravity and the pressure under which the metal is cast is dependent upon the height of the gates and risers. In centrifugal casting the metal is forced against the mold wall and into the cavities under much higher pressures, due to centrifugal force imparted by the revolving mold.

Generally, there are three methods of centrifugal casting: True centrifugal casting, semicentrifugal casting and centrifuging. The true centrifugal method consists in spinning the casting about its own axis and using centrifugal force to hold the metal on the wall of the mold, thus forming the inside without the use of a center core. When a mold is spun about a horizontal axis, the interior cavity formed by the molten metal is a true

Abstract of a paper presented at the recent spring meeting of The American Society of Mechanical Engineers in Birmingham, Ala.

Fig. 2—Below—Mold for making cast iron pipe employs short core to form socket end. Inside diameter is formed to a true circle by centrifugal force



cylinder, regardless of the shape of the outside of the casting. Its inside diameter is determined by the volume of metal poured.

If more than one inside diameter is required in a casting, the larger inside diameter may be formed by cores extended from the ends of the mold, leaving the smaller diameter to be formed by centrifugal force. *Fig.* 2 shows the conventional mold for making cast iron pressure pipe. Note that the inside diameter of the socket is larger than the pipe inside diameter and is made with a core.

This method has been used in the mass production of cast iron pipe for more than twenty years. During that period both sand-lined mold and metal-mold processes have been in successful commercial use and their economic soundness has long since been proved. Higher physical properties have been obtained and this has resulted in a reduction in the required thickness and weight of the pipe for a given service. Alloy steel gun barrels are centrifugally cast in horizontal metal molds by a process developed over a long period of years at Watertown Arsenal.

True horizontal centrifugal casting is well adapted to the manufacture of short and long tubes in various sizes where the inside cavities are cylindrical. Steel tubes, ranging from several inches in diameter up to 50 inches in diameter, can now be made by the author's company in lengths of 16 feet. Typical products of this method are pipe, various kinds of tubing, radial engine cylinder barrels, *Fig.* 1, hollow shafting for ships, weld-neck castings, bearings, sleeves, etc.

True centrifugal casting is done also by spinning the mold about a vertical or an inclined axis. The resulting interior cavity is a paraboloid the shape of which is dependent upon the speed of rotation of the mold, the diameter of the closing fixture at the top of the mold, and the angle of inclination of the axis rotation. Assuming a fixed diameter at the top of the inside cavity and

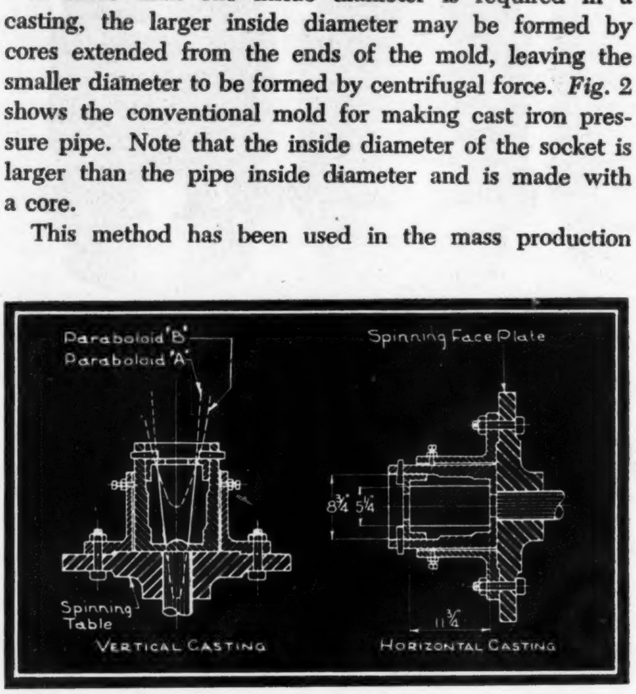


Fig 3 — Above — Alternative methods of centrifugally casting radial engine cylinder barrels. In horizontal casting the inside surface is a true cylinder, in vertical it is a paraboloid

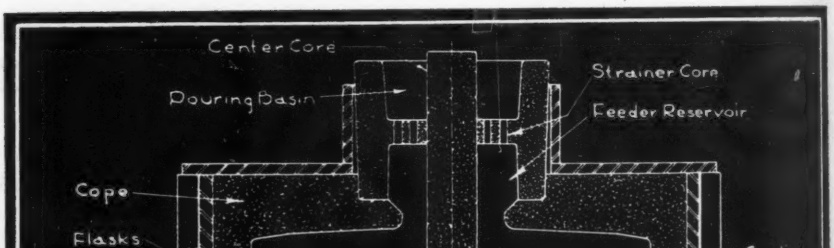


Fig. 4—Right—In semicentrifugal casting the center cavity, if any, is formed by a core, and the metal feeds from a reservoir. Part shown in the mold is an engine flywheel

Fig. 5—Right—Engine flywheel cast by semicentrifugal method in vertical axis machine without center core

a fixed angle of inclination, the depth of the paraboloid is increased by an increase of speed. *Fig.* 3 shows radial engine cylinder barrels being cast by the horizontal and by the vertical methods. At the right the mold is spun about a horizontal axis and the inside cavity is cylindrical. At the left the mold is spun vertically and the inside cavity is parabolic in shape. At a certain speed of rotation the inside cavity will take the shape of paraboloid "A" as shown, while at some lower speed the inside cavity will be formed on the line of paraboloid "B". In each case the top diameter of the inside cavity will be larger than the bottom diameter. These castings (8¾ inches outside diameter by 11¾ inches long) are now being made horizontally at speeds of 975 revolutions per minute and lower, and vertically at speeds approaching 1800 revolutions per minute. The mathematics for calculating the shape of the inside paraboloid is relatively simple.[*]

The horizontal and vertical methods of producing castings have many advantages. In static castings a large proportion of the critical defects are subsurface imperfections detectable only by expensive and time-consuming methods. When spun, the impurities such as dirt, sand and slag, having lower specific gravity, are forced to the inside surface of the casting by the difference in centrifugal force. Any gas or air pockets likewise are eliminated. Elimination of these foreign inclusions results in a sounder casting and the product is more uniform. Further, a centrifugal casting is more dense than a static casting. It is doubtful that the method of casting steel would change the specific gravity of the metal, but freedom from foreign inclusions or voids naturally would make a casting more dense, or rather, heavier per unit volume.

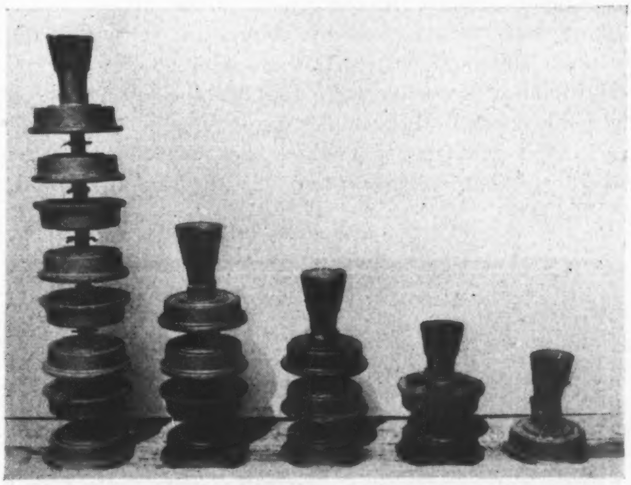
Gives Favorable Directional Solidification

Directional solidification is highly important in any method of molding. In true centrifugal casting this comes natural, since the metal is cooled from the outside toward the center. Elimination of inside cores greatly reduces the costs in the foundry, as well as in cleaning. Elimination of gates and risers greatly increases the yield, and in some cases 100 per cent yield is obtained, as in cast steel hollow ship shafts, various tubing, cast iron pipe, etc., where inside machining is not required. In castings such as radial engine cylinder barrels where the inside machined surface is highly important, the wall is poured thicker than required. This extra thickness on the inside serves much as an inside gate or feeder and is later removed by machining. Thus in such cases the actual yield is lower. The centrifugal method is highly adaptable for mass production of identical castings.

Semicentrifugal casting also involves spinning a casting about its own axis—usually the vertical axis. If the casting has a center cavity, this cavity often is formed with a center core, and the casting fed by a center gate passing down around this core, *Fig.* 4. In many cases the center is cast solid as in the case of the flywheel shown in *Fig.* 5 and the center cavity, if any, is machined out or removed by an oxy-acetylene torch.

Metal molds and a combination of metal and sand molds also are used. Stack molding, where a number of castings are made in one pour, is well adapted to this method, the possibilities of which are illustrated in *Fig.* 6. On

Fig. 6—Below—Tractor wheels cast in stacks by semi-centrifugal method. Yield increases with number of layers



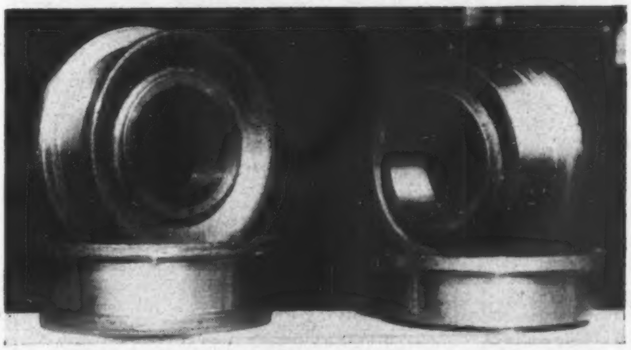


Fig. 7—Above—Track wheel rims for crawler-type tractors are centrifugally cast of high-carbon steel for special quench heat treatment

Fig. 8—Left—Idler wheel hubs centrifugally cast in horizontal-axis machine with sand-lined molds and cores

[*]R. F. Wood—Patent No. 1,533,780.

the right of the photograph is a wheel casting made one in a mold, while at the extreme left it will be noted that eight castings are made on the stick. The only limitation on the number of layers used in stack molding is the convenience and economics of the handling.

Often it is found advisable to change somewhat the design of the casting to favor gating, feeding, and directional solidification in order to obtain more uniformly sound castings. Ordinarily this can be done without altering the usefulness of the casting, if the engineer and foundryman will cooperate. Most successful foundries have found it necessary to carefully engineer each job that is to be spun, and many jobs are found better suited for static molding.

Speed of rotation in semi-centrifugal casting is lower than that used in true centrifugal casting, hence the centrifugal pressure is less. However, this rotation keeps the liquid metal in motion. The action aids in flowing the metal into all of the cavities of the mold and in more completely feeding the casting. It further insures against blows and voids caused by contraction during solidification. This produces sounder and more uniform castings. The method is particularly adaptable for casting wheels, gear blanks and other circular shapes.

In the centrifuging method the molds forming the useful castings are positioned near the periphery of the

Fig. 9—Centrifuge casting of bogie wheel hubs, five pieces being made in one mold. Method is adaptable to the forming of many odd-shaped castings

revolving table. The metal is poured into a gate located on the axis of rotation and is fed into the molds by radial sprues. Centrifugal force is used merely to provide liquid pressure. Usually two or more castings are made in each mold.

One of the earliest applications of this method is the old-time inlay casting machine used in dentistry. A plaster-of-paris mold is attached to one end of an arm. The other end of the arm is pivoted to and supported by a pedestal, the arm being free to revolve around the pivot. Molten gold is poured into the mold and the mold rapidly spun around the pivot. The centrifugal force of spinning forces the molten gold into the intricate cavities of the mold, resulting in a sound casting accurately shaped.

A typical example of centrifuging is shown in Fig. 8 where five bogie wheel hub castings are made in one mold. The center gate with the five radial sprues to feed the castings is shown. In this case a core is used to form the inside cavity of each casting. This method is also well adapted to stack molding and many odd-shaped castings are made by this process.

Increasing the Yield

Advantages of centrifuged castings are substantially the same as obtained in semicentrifugal casting. Yields above 85 per cent have been reported on jobs where formerly in static casting they were less than 50 per cent. On single-mold casting by the semicentrifugal method, yields have been increased from approximately 30 per cent to more than 70 per cent. The casting machines can be of simple construction, and therefore not too expensive either in first cost or in maintenance. Floor-type units may be used which can be moved from one location in the foundry to another at little cost or inconvenience.

In the manufacture of centrifugal castings a wide variety of mold speeds is used. The terms usually referred to are "peripheral velocity" and number of "times gravity" centrifugal force or pressure against the mold wall. Casting speed is linked with a number of other factors such as pouring time, size and shape of casting, wall thickness, method of centrifugal casting being used, and others.

Exacting Specifications Met

Physical properties of steel castings made centrifugally have been highly satisfactory. Many exacting specifications that were not thought possible a few years ago are being met constantly in producing engineering parts. The ability to consistently produce sound homogenous castings has made this possible. The present emergency has given sharp impetus to the development and production of centrifugal steel castings, not only as an improvement on the static casting methods but also for making parts formerly thought possible only by forging. Most of the physicals of these castings have been found to compare favorably with those of forgings and in many cases to be better, depending upon how the casting is used.

No one experienced in the art would venture to say that these methods of molding will revolutionize the steel foundry industry or replace the great bulk of work done by forging. The size and shape of the casting place definite limitations on the process. However, the centrifugal method of casting is ideally suited for producing a vast variety of work. It is a relatively new method that is rapidly finding its place in the economic production of high quality engineering parts.

Theory and Design of Enveloping Worm Drives

By Dietrich W. Botstiber
Consulting Engineer

According to the type of application gear drives may be divided into power transmission drives and control drives. The less space a power transmission drive needs and the less energy it puts into friction, the better it will stand in the battle for space and efficiency. The more accurately a control drive translates the motion of the driving member, the more applicable it will be to use in precision instruments and control devices.

As a special form of gear drive the worm drive has many characteristic features, some of which may mean considerable advantage for a certain application. The large ratio obtainable with only two moving parts and the smooth flow of power may be called the most distinctive advantages. Undesirable are the great sliding friction, resulting in low efficiency and increased backlash due to wear and, in some cases, the lack of reversibility of the flow of power.

Greater strength and better sliding qualities of the materials and higher accuracy in manufacturing will increase capacity, efficiency and accuracy, but on a standard worm drive the improvement is kept in rather narrow limits. Contact between the teeth of worm and gear takes place only along one or, at the most, two short lines created by the contact of two convex surfaces. Elastic com-

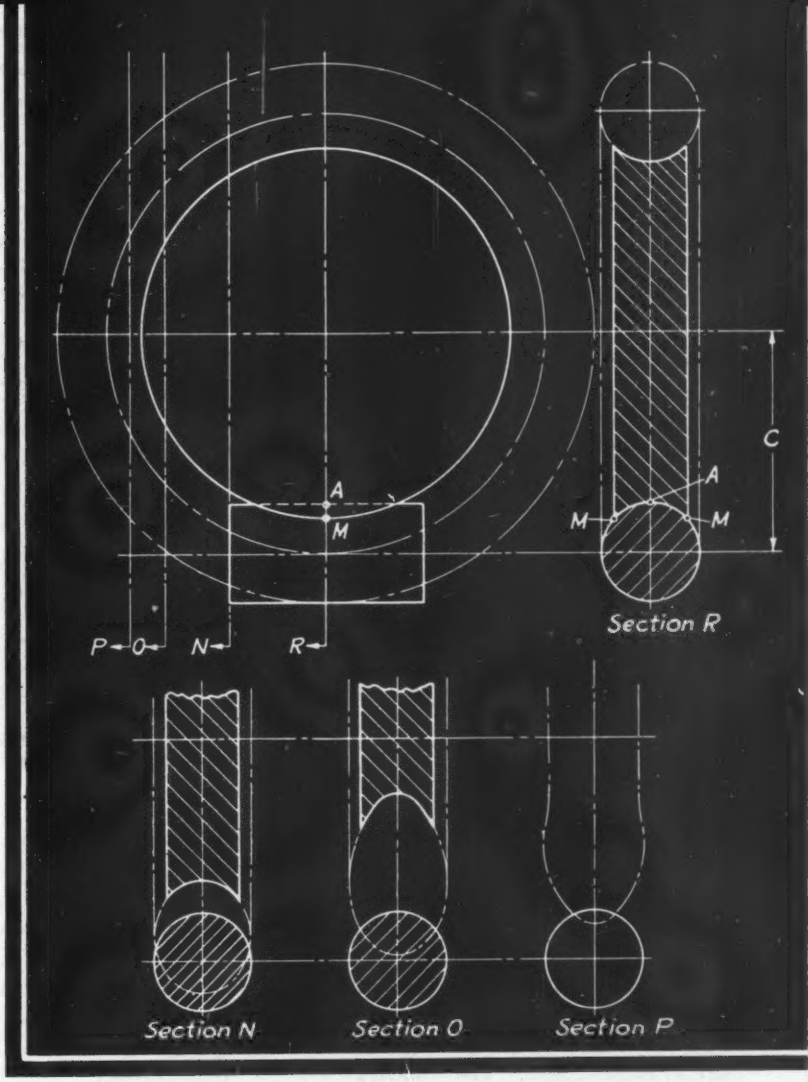
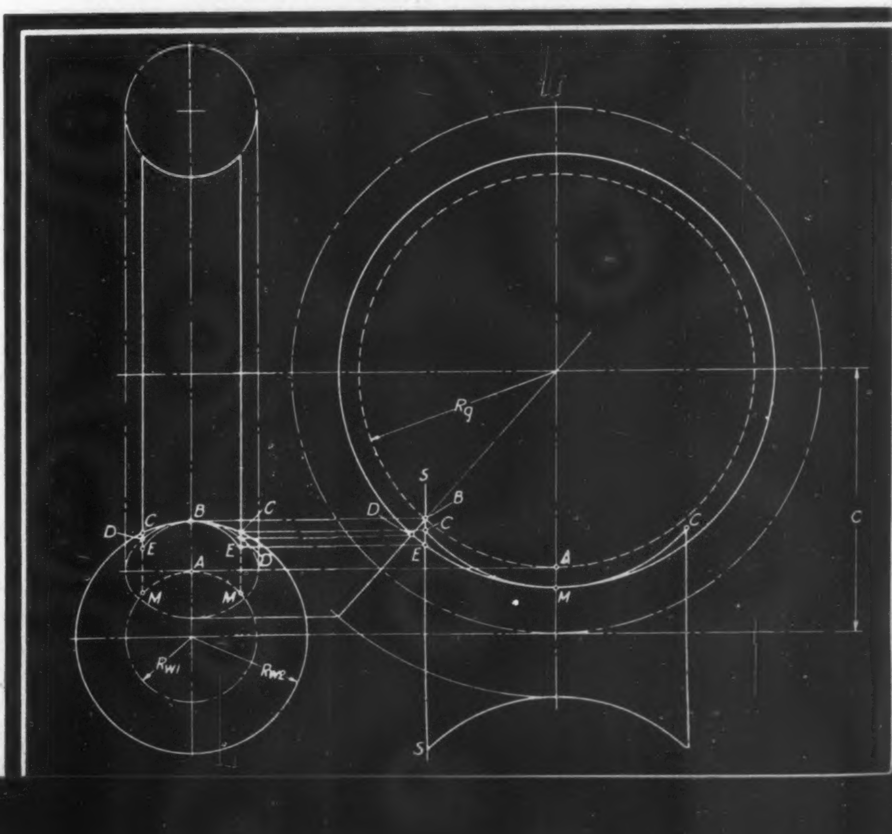


Fig. 1—Above—Pitch figures of conventional worm and worm gear match each other only at the section R. Other sections clear as shown

Fig. 2—Below—Contact condition for basic globoid worm and gear would involve interference below the line CMC in the right-hand view



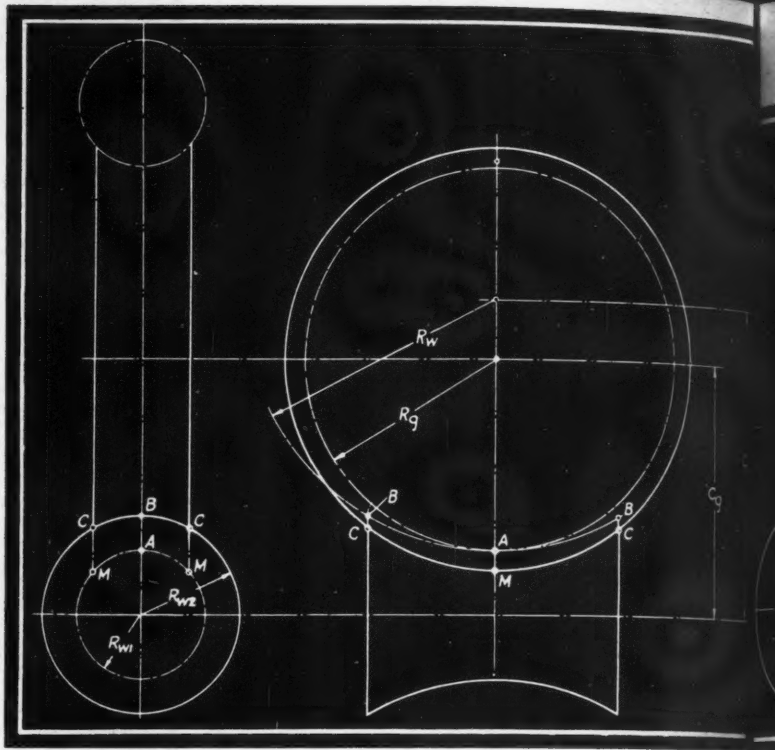


Fig. 3—Right—Modified worm with increased pitch profile radius is designed to avoid interference with the basic gear

pression of the materials changes this theoretical line into a practical area which carries the full tangential force created by the driving power. The resulting high unit pressure tends to break the film of lubricant between the teeth and the wear of the sliding surfaces sets a considerably lower limit to the capacity than the breaking strength of the teeth. Therefore any improvement in the contact condition of the meshing teeth will result in an increase of power capacity and in reduction of wear and backlash.

Endeavors in this direction have led to the development of a particular type of worm drive known as enveloping worm drives, hour-glass worm drives, or spheroid or globoid worm drives. Compared with a standard worm drive of equal size and quality, the globoid drive will permit from 60 to 100 per cent increase in load or, for a given load, will permit reduction in overall dimensions from 30 to 50 per cent.

The field of application for this type of worm drive is greater than is generally realized. Wherever large ratios, small dimensions and freedom from backlash are important, a globoid drive may be the solution. Elevating and hoisting machines use this type of drive to a large extent. The rudders of large ships, driven over a worm gear segment by one or two electric motors with globoid worms on the shaft extension, represent examples of a drive where the small dimension and the self-locking feature of the globoid drive is most favorably combined. For gun turrets of battleships, and for the elevating mechanisms of large-caliber guns, requiring smooth and uniform slow-speed operation, the globoid drive represents the solution to an important problem. Typical applications for control motions are variable-pitch propellers, steering gears for cars and trucks, precision worm drives in fire-control computers and position indicators, and adjusting units in optical sighting instruments. On these drives the freedom from backlash is a decisive factor.

Major problem of the globoid drive is usually its manufacture. Basically the cutting operations for globoid gears are not essentially different or more difficult than many other gear-cutting operations, and the design and development of machinery for this purpose does not involve major mechanical problems, once the basic requirements are correctly conceived. The theoretical conditions of this type of gearing and their application to its manufacture, will be analyzed in this article.

On a standard worm gear drive the pitch figure of the worm is a cylinder, that of the gear is a spheroid. A spheroid or globoid will, in the following, be considered to be a figure generated by the rotation of a circle, whatever the relation between the size of the circle itself and the location of the axis of rotation may be. A special case of a globoid occurs when the axis of rotation goes through the center of the circle, giving a sphere. Another typical globoid is the circular ring, the most popular representative of which is a doughnut.

The pitch figure of a worm gear is such a circular ring. Diameter of the rotated circle is usually made equal to the pitch diameter of the worm and the radius of

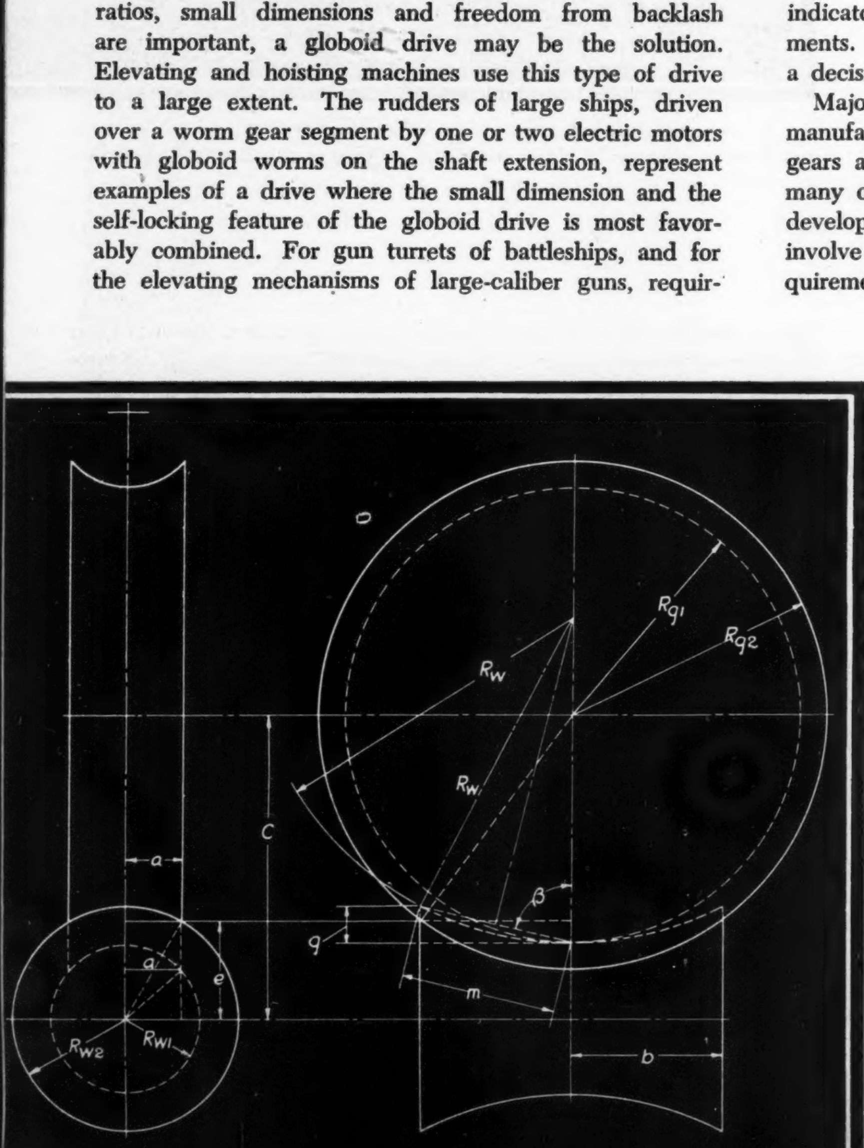


Fig. 4—Left—Formulas for the proportions of a drive with modified worm are derived from the dimensions on this diagram

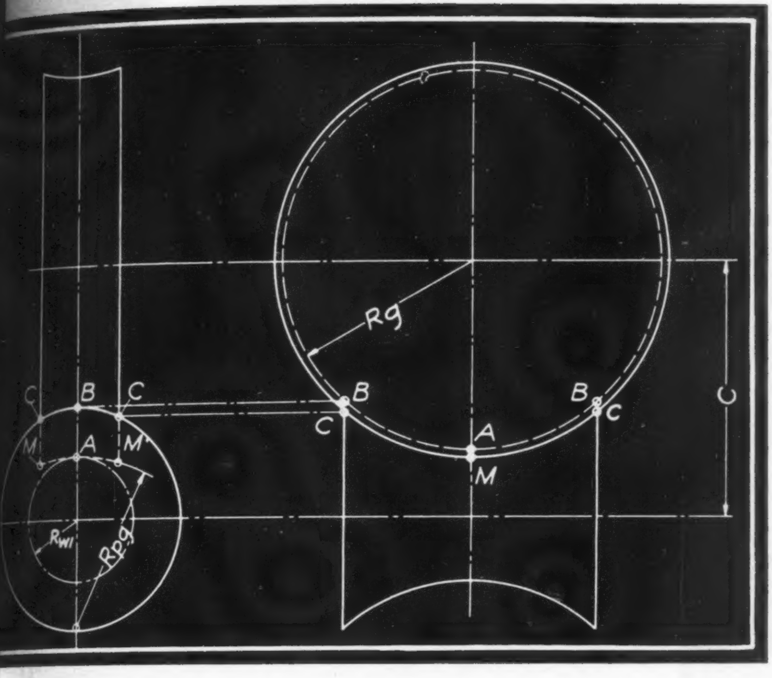
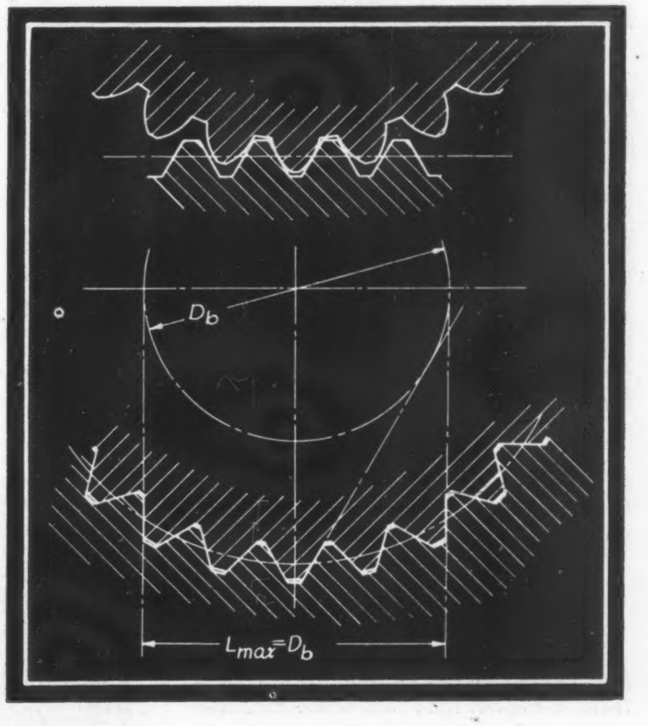


Fig. 5—Left—Modified gear with increased pitch profile radius is designed to avoid interference with the basic worm

Fig. 6—Below—Sections through cylindrical (upper view) and globoid (lower view) worm drives show difference in engagement



rotation equals the center distance. There are deviations from this rule, usually caused by the method of manufacturing. As the shape of the gear cannot be "wrapped" around the worm, the width of the gear must be smaller than the worm diameter. The basic shape of a worm gear, therefore, is the shape that remains when the space within a circular ring is limited by two parallel planes, vertical to the ring axis.

Shown in *Fig.* 1 is the familiar schematic picture of a worm drive. In section *R* the shape of the gear matches the worm perfectly along the arc *MAM*. In any other section there is a distance between the worm and gear. In *Fig.* 1 the rest of the circular ring, forming the pitch figure of the gear, is shown in the sections. Through *N*, *O* and *P*, this section outline is not circular but shows the typical odd shape of the various sections of a circular ring.

Area Contact Impossible

In order to change the contact between worm and gear from line contact to area contact the profile of the worm must match that of the gear, that is, it must be part of a circular ring of the same dimensions and same location as the gear. This would mean a curved centerline for the worm and is therefore practically impossible.

The next nearest step in approaching a solution consists in making the worm another globoid whose profile matches the pitch circle of the gear. Then the worm has the same type of shape as the gear, that is, the space within a circular ring limited by two planes vertical to the axis. The two parts of a globoid drive, therefore, are of the same basic shape, with different proportions. The contact condition of two such figures is shown in *Fig.* 2.

Profile of the gear is the arc *MAM*, part of the circle with the radius R_{w1}, which is equal to the throat pitch radius of the worm. The gear throat pitch circle with radius R_g, when rotated around the centerline of the worm, will generate the circular ring around the worm.

In a section through the vertical centerline the pitch lines coincide over the full arc *MAM* (left side view). In any other section conditions seem different. In section *SS* the worm has the radius R_{w2}. The section through the gear produces the typical section of the circular ring, part of which (within the limits of the actual gear) is shown as curve *EBE*. Since one figure is a circle and the other a curve similar to an ellipse, they cannot coincide over their full length or over any part of it. They meet in *B*, as shown. In any section outside the vertical centerline (smallest worm diameter) the worm will interfere with the gear, and curve *CMC* in the right

side view represents the intersection line. In order to eliminate this interference one of the two members must deviate from that principal globoid form. This deviation may be done either on the gear or on the worm or on both. In the following, a gear or worm whose pitch figure is made according to *Fig.* 2 will be called a "basic gear" or "basic worm" and any gear or worm deviating from that shape will be called a "modified gear" or "modified worm", respectively.

For the globoid drive with modified worm the pitch figure condition is shown in *Fig.* 3. The pitch profile radius of the worm R_w, right-hand view, is increased so that interference of the pitch figures is avoided. The gear has the shape of the basic gear. The smallest permissible size of R_w is determined by the condition under which the worm will match the gear in the throat plane of the worm along the arc *MAM*, and also contact the gear in the four points *C*. Any decrease of R_w will then create interference, any increase of R_w will increase the clearance outside of the throat plane.

Computing Pitch Profile Radius

Computation of R_w may be done by the following formulas, in connection with *Fig.* 4.

$$R_{g2}=C-\sqrt{R_{w1}^2-a^2} \qquad (1)$$

$$e=C-\sqrt{R_{g2}^2-b^2} \qquad (2)$$

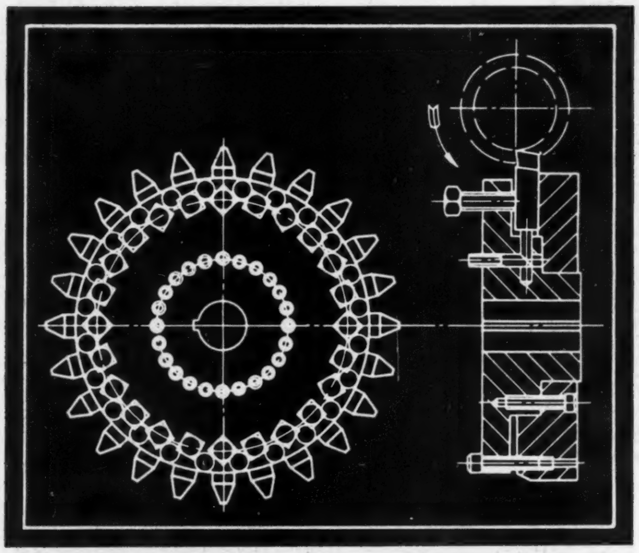
$$R_{w2}=\sqrt{e^2+a^2} \qquad (3)$$

$$g=R_{w2}-R_{w1} \qquad (4)$$

$$m=\sqrt{b^2+g^2}, \quad \cot\beta=\frac{g}{b} \qquad (5)$$

$$R_w=\frac{m}{2\cos\beta} \qquad (6)$$

Obviously for either width of gear, $2a$, or length of



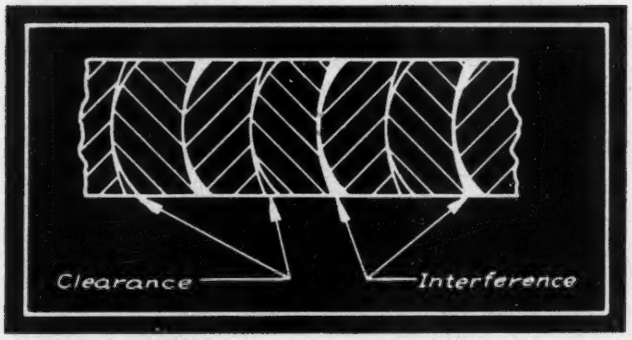


Fig. 7—Top—Cutter head for producing basic globoid worm has teeth representing section through throat plane of gear

Fig. 8—Above—Curvature of the gear teeth is smaller than that of the modified worm teeth, causing interference on one side which is removed by second cut

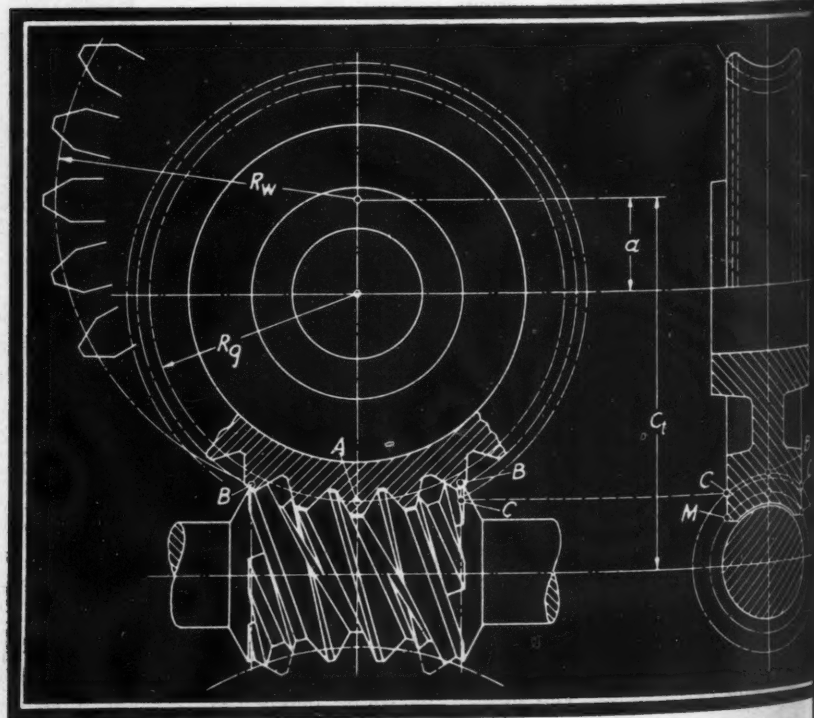


Fig. 9—Right—Corrected modified worm drive with proportions outside the practical range shows the two sets of threads resulting from the two cuts

worm, $2b$, reduced to zero, R_w will equal R_{g1}, that is, the basic worm will fit a gear consisting of a thin disk shaped like a section through the center plane, and the basic gear will fit a worm of length zero. The practical maximum values for a and b depend on the shape of the teeth, as will be shown later.

In *Fig.* 5 is shown the pitch figure condition for the globoid drive with modified gear. Interference is eliminated by increasing the pitch profile radius R_{pg} of the gear; the worm is of basic shape. Contact between gear and worm is obtained over the arc *BAB*, but this contact exists only in the center plane. R_{pg} is greater than the largest worm radius, and actually equals the curvature radius of the section through the basic circular ring, taken radially at B and projected into a plane parallel to the vertical centerline.

The foregoing considerations indicate two ways for design and manufacture of globoid drives. In each case the correct shape of pitch figure and tooth profile may be obtained either by copying a tool of opposite shape and feeding it into the blank, or by generating the teeth

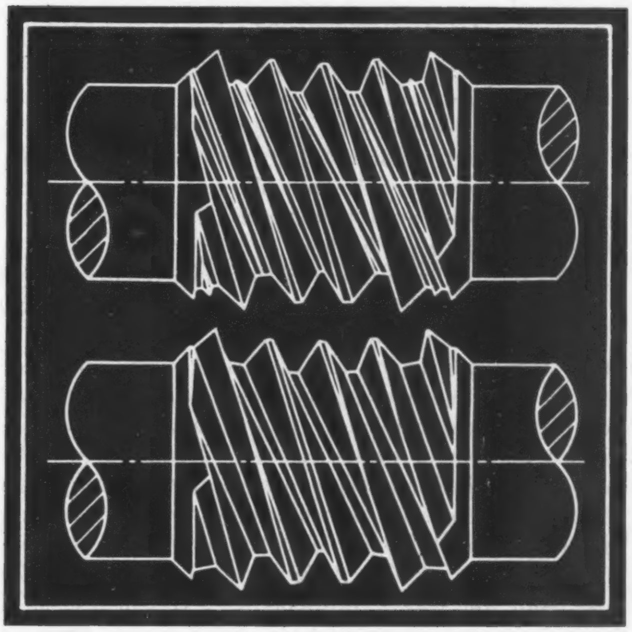


Fig. 10—Above—Corrected modified worm before (top) and after removal of edges remaining from intersection of two sets of threads

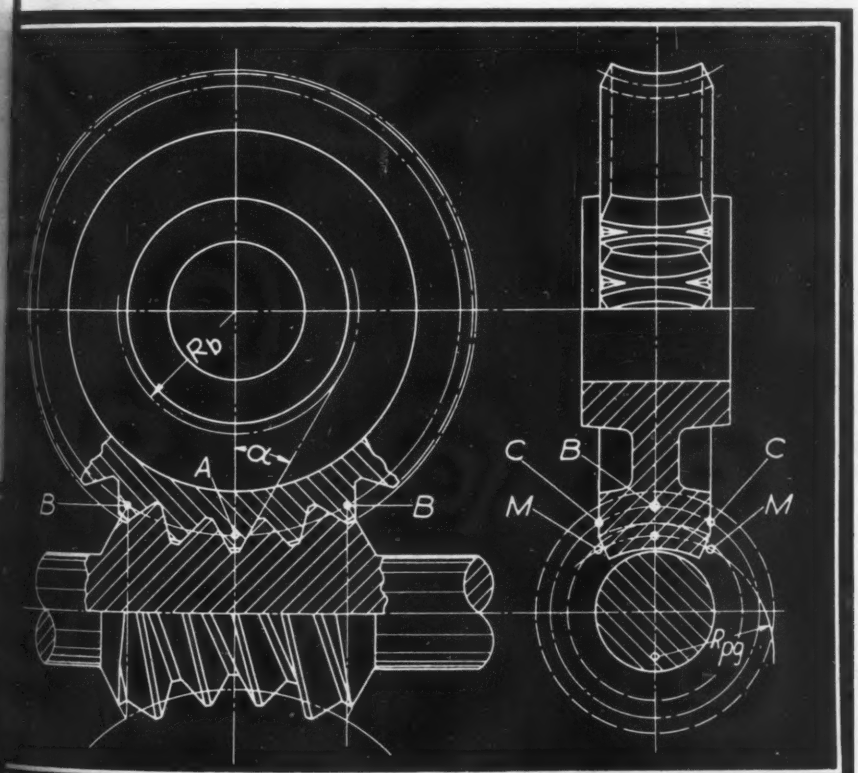
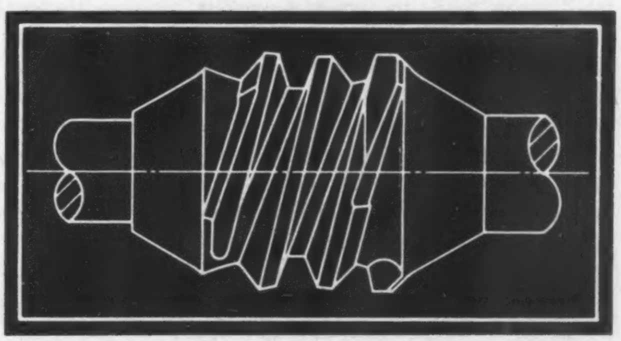


Fig. 11—Left—Drive with modified gear has complete tooth contact over full length of worm in center plane

Fig. 12—Below—Basic worm made by special patented method which provides compensation for reduction of cutter teeth due to regrinding



by a tool shaped like the mating gear (or worm). This leads to four basic methods:

For drives with modified worm:

1. A basic gear is produced in tool steel, its teeth are converted into rows of cutters, and this tool is used for generating a modified worm. The gear is produced in the same manner as the first operation on the cutter.
2. A basic gear and a basic worm are produced and the worm is modified by a special operation.

For drives with modified gear:

3. A basic worm is produced in tool steel, its teeth are

converted into rows of cutters, and this hob is used for generating the gear. The worm is made in the same way as the first operation on the hob.

4. A basic gear and a basic worm are produced and the gear is modified by a special operation.

Selection and application of any of the foregoing methods is limited by the difficulties in making the correct cutting tools. Some of the tools and cutting methods are described in the following.

Although the basic gear has the same pitch figure as a gear for a cylindrical worm of equivalent dimensions, there is an essential difference in the shape of the teeth. Since the pitch figures of the basic worm and gear coincide over a certain range, the teeth on worm and gear will match completely. *Fig.* 6 shows the basic difference between a cylindrical and globoid drive. The gear for a cylindrical worm must clear the teeth of the worm in any position (like the teeth of a spur gear meshing with a rack), which leads to the familiar involute shape. On the globoid drive a certain position of the gear tooth will always correspond to a certain portion of

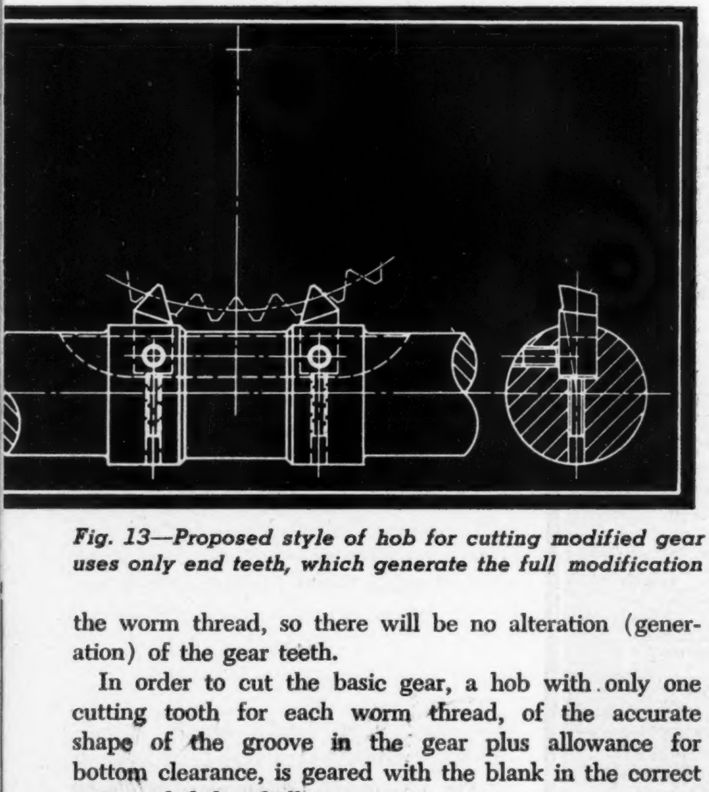


Fig. 13—Proposed style of hob for cutting modified gear uses only end teeth, which generate the full modification

the worm thread, so there will be no alteration (generation) of the gear teeth.

In order to cut the basic gear, a hob with only one cutting tooth for each worm thread, of the accurate shape of the groove in the gear plus allowance for bottom clearance, is geared with the blank in the correct ratio and fed radially.

The basic globoid worm, in analogy to a cylindrical worm, is cut by a tool or set of tools advancing along the pitch profile while the blank is turning. Because the pitch profile is a circular arc, the motion of the tool is circular. A cutter head for this operation is shown in *Fig.* 7. Cutting edges of the teeth represent a section through the throat (center) plane of the gear.

Method 1 (generated modified worm) has so far not been utilized for actual manufacturing. Its principle, however, deserves consideration because it may lead to another way of performing method 2.

Method 2 (corrected modified worm) is used to some extent and is known as the Hindley gear. The basic gear is cut by a single-tooth hob, and the basic worm bv a cutter head such as the one shown in *Fig.* 7. Then the worm is modified according to *Fig.* 3. This is done by increasing the cutter head pitch radius from R_g to R_w. The clamping screws of the tools are loosened, the tools removed and spacers of a length $R_w - R_g$ are inserted. Then the tools are put back and clamped in place. In the first cut the worm blank and cutter are fed to C_i (*Fig.* 3), in the second, to C_t.

Considering that on the actual gear and worm the pitch figures are formed by rows of teeth (in which the location of a certain tooth thickness represents the pitch figure) and visualizing the shape of such teeth in a location outside of the vertical centerline, it is found that the interference takes place on only one side of the teeth. The centerline of each tooth in the gear is directed radially outward and the curvature of the gear tooth is smaller than that of the worm. As shown schematically in *Fig.* 8, one side of the worm teeth would create interference, and is removed by the second cut, modifying the inner side of the worm teeth to conform with the profile radius R_w. In this way the worm is formed by superimposing two threads or sets of threads. *Fig.* 9 shows a drive whose proportions were selected outside of the practical range, to show clearly the two sets of threads. The edges remaining between the teeth should be removed after cutting. Since one side of the teeth is cut away, only half the number of teeth can take pressure in one direction. Actually part of these teeth is cut away by the modifying cut and the amount removed increases with the distance from the center (throat). Shorter worms, therefore, will give more efficient use of material and labor than longer ones. The maximum length is determined by the pressure angle, as shown on *Fig.* 6.

Tooth Thickness Decreases Toward Outside

In *Fig.* 10 is shown a worm of good practical dimensions, manufactured by this method. In the upper view the worm is shown as it comes from the machine, in the lower after the edges remaining from the intersection of the two sets of threads have been removed. Typical for all worms of this type is the gradual decrease of the tooth thickness toward the outside.

The cutting condition of the cutters entering the inclined threads of the worm is severe, especially on drives with steep helix angles (multiple threads). It is difficult to keep favorable rake and relief angles, and wear of the tools and regrinding will change their shape. In principle, one cutter for each thread is sufficient to cut the worm or, if the ratio of the drive is an irrational number, one cutter will cut all threads in the worm. It is advisable, however, to make several cutters, usually as many as the design of the tool permits, and to grind the cutters so that certain cutters only cut certain portions of the thread profile. Tools must be ground in fixtures to secure the correct shape, and must be raised by shims after regrinding, to compensate for the lowering of the cutting edge. Cutters are held in radial slots in one part of the cutter-head body, and must be radially adjusted to the correct center distance. The cutter head shown in *Fig.* 7 provides setscrews acting over pins flattened at 45 degrees, so the radial adjustment may be done from the top. Correct design of the cutter head and careful mainte-

(*Concluded on Page* 186)

Factors Influencing Design of Foundry Conveyors

Fig. 1—Above—Mechanical shakeout is fundamentally a vibrating deck or grid

By F. B. Henry and G. N. Wileman

The Jeffrey Mfg. Co.

GENERAL rules that should be kept in mind when designing equipment for use in the foundry include: (1) Friction parts should be entirely enclosed if possible, particularly those parts having high loads, due to the extreme abrasive nature of foundry sand and dust. This practically eliminates, or keeps to a minimum, all sliding types of conveyors. (2) Points in the system where dry sand is transferred from one conveyor to another, or from conveyor to bins, should have properly designed chutes and hoods for removal of dust, steam, smoke, and gases. Individual installations should be designed to meet state-law requirements. (3) Chutes and hoppers handling prepared or damp

Abstract of a paper presented at the annual meeting of the American Society of Mechanical Engineers in New York.

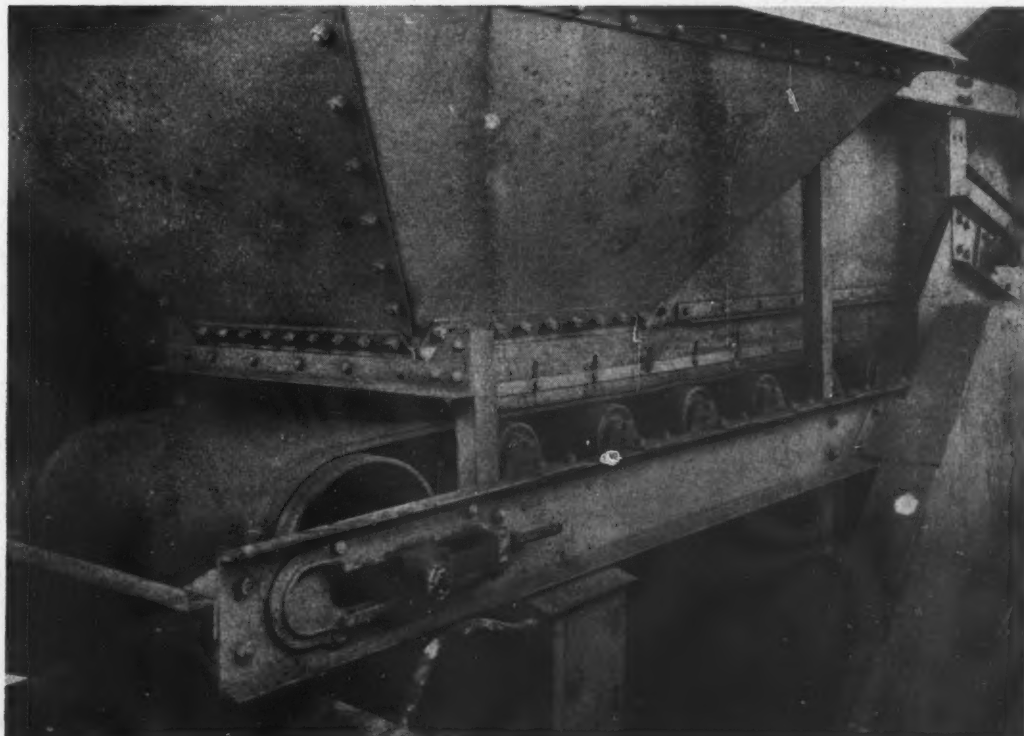
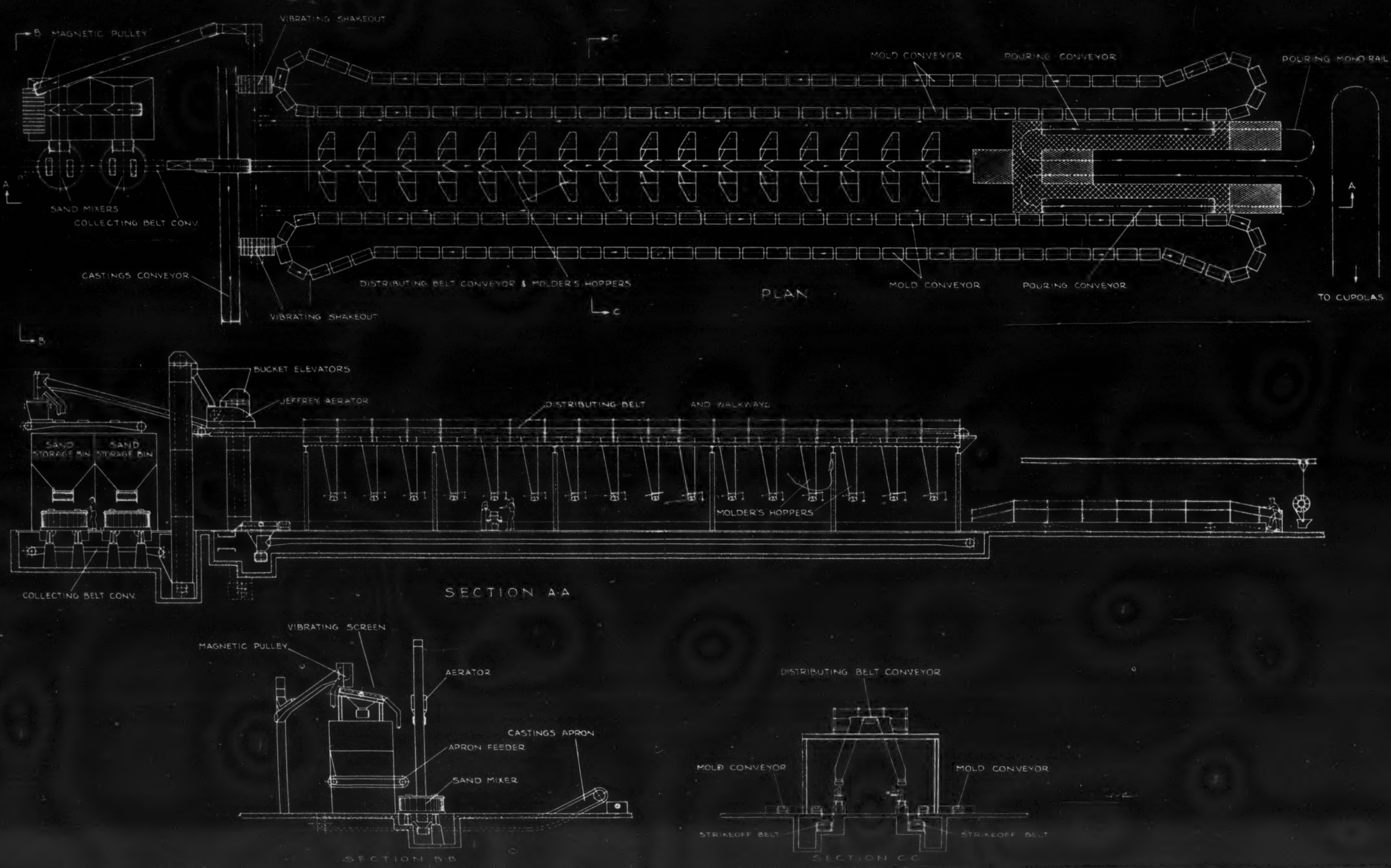


Fig. 2—Right—Belt feeder requires closely spaced idler rollers under the load



B
MAGNETIC PULLEY
VIBRATING SHAKEOUT
C
MOLD CONVEYOR
POURING CONVEYOR
POURING MONO RAIL
A
SAND MIXERS
COLLECTING BELT CONV.
CASTINGS CONVEYOR
DISTRIBUTING BELT CONVEYOR & MOLDER'S HOPPERS
VIBRATING SHAKEOUT
MOLD CONVEYOR
POURING CONVEYOR
PLAN
TO CUPOLAS
BUCKET ELEVATORS
JEFFREY AERATOR
DISTRIBUTING BELT
AND WALKWAYS
SAND STORAGE BIN
SAND STORAGE BIN
MOLDER'S HOPPERS
COLLECTING BELT CONV.
SECTION A-A
VIBRATING SCREEN
MAGNETIC PULLEY
AERATOR
CASTINGS APRON
APRON FEEDER
SAND MIXER
SECTION B-B
DISTRIBUTING BELT CONVEYOR
MOLD CONVEYOR
MOLD CONVEYOR
STRIKEOFF BELT
STRIKEOFF BELT
SECTION C-C

sand should have angles of at least 60 degrees, rounded corners, and generous cleanout doors.

Before considering the individual types of conveyors used in the various applications, and their design features, it may be well to consider the layout of a typical high-production, continuous, gray-iron foundry such as shown in *Fig.* 3 on opposite page. This arrangement lends itself to any foundry, steel, gray iron, malleable iron, aluminum, or magnesium, having high production of duplicate castings, with continuous hot metal available. Sand is prepared in the mixers, aerated, and distributed to the molders' hoppers at each molding station. After the mold is completed it is placed on the mold conveyor for pouring, cooling, and conveying to the shakeout station. Sand passes through the shakeout machines, is screened, and conveyed to the storage bin for another cycle. The castings are collected from the ends of the shakeout machines and conveyed to the cleaning room.

Following is a detailed discussion of the various types of conveyors used in typical systems:

Shakeout: The mechanical shakeout (*Fig.* 1) is now widely used in all types of foundries and is available for molds from small snap molds, weighing possibly 100 pounds, to large molds weighing as much as 50 tons. They consist fundamentally of a vibrating perforated deck or grid on which the mold is placed, the sand falling through the grid to the conveying means underneath, with the flask and casting remaining on the grid or being discharged from one end. Large molds frequently are stripped before being shaken out. Supports for shakeout machines must be extremely heavy and rugged.

Fig. 3—Opposite page—Layout of equipment for a typical high-production, continuous, gray-iron foundry

Feeder Under Shakeout: Means must be provided for conveying the sand from the hopper underneath the shakeout machine. This hopper is always designed to contain at least the total amount of sand in the largest mold being handled. This sand frequently is very hot and may contain considerable metallic refuse such as gaggers and rods, as well as fins, sprues, and so on, which may be broken from the casting in the shakeout process. There are three types of conveyors used for feeding the sand from the shakeout:

(*a*) A belt feeder, *Fig.* 2, sometimes is used in cases where the castings are light and the sand does not contain any material amount of metallic refuse such as in a foundry making light iron or brass castings. Closely spaced idlers or flat steel plate are required under the load.

(*b*) Apron feeders, *Figs.* 4 and 5, commonly are used for this service, and where used should be of the leakproof type, with a tight-fitting enclosed outboard roller. Pans have welded ends to prevent leakage of dry sand, and are removable from the conveyor without dismantling the chain. The drive should be protected by a shear pin or similar device. While the apron will stand heat in a satisfactory manner, damage frequently results to the pans from gaggers or rods

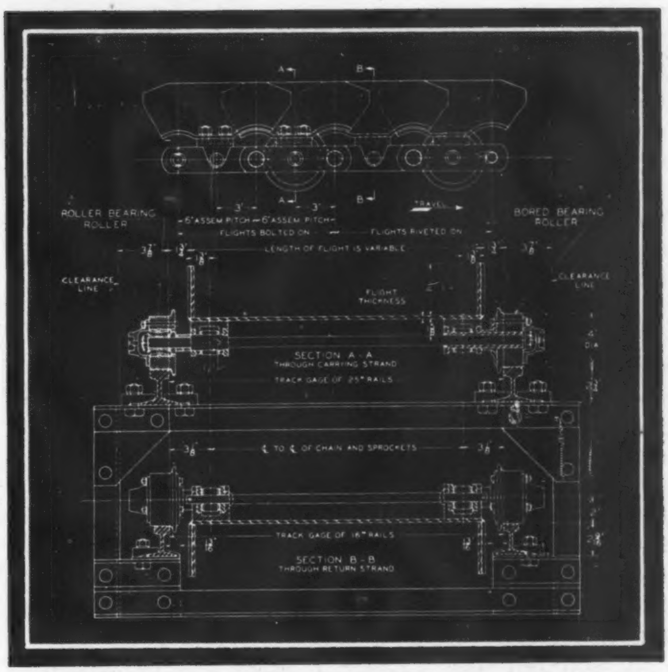
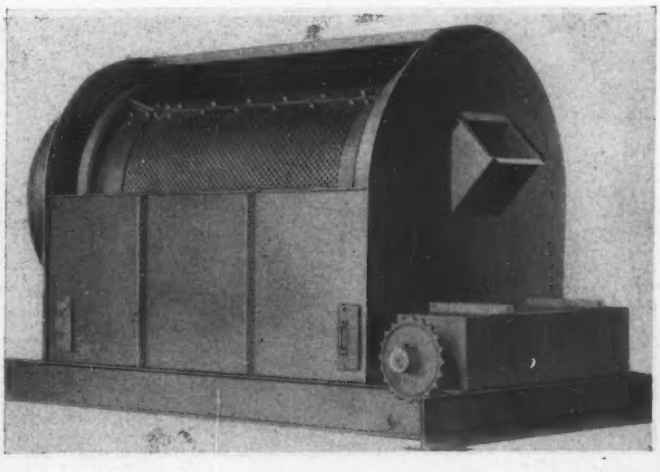


Fig. 4—Above—Section through typical apron feeder showing details of the shafting, rollers and structure

Fig. 5—Above—Apron feeder under shakeout. Pans are readily removed and have welded ends

Fig. 6—Below—Rotary type breaker screen has lump-breaking and sand-cooling action. Is used generally for heavy work



which get through the shakeout grating.

(*c*) During the last few years, the electrical vibrating feeder has come into wide usage in this application. It offers a perfectly smooth deck with no obstructions for rods or gaggers, can stand the heat without injury, and is free from dribble since it has no return run.

Belt Conveyor Having Magnetic Pulley: In the usual installation, sand is fed from the shakeout hopper to a belt conveyor equipped with a magnetic head pulley, for removal of magnetic refuse such as gaggers, rods, nails, sprues, shot, and so on. This is important for various reasons. It is essential that foreign material be removed to prevent injury to some of the other parts of the equipment. Gaggers and rods are salvaged for reuse. Sprues, shot, and other parts of the casting metal are returned for remelt. A rubber belt is used when the sand is comparatively cool, with heat-resisting, impregnated-fabric belts for hot sands. Belt-conveyor idlers should have a high-pressure type of lubrication which forces out the old grease. Closely spaced idlers or a plate should be placed under the loading point of the conveyor to take the load.

A short belt with a magnetic pulley may be applied over the main belt for picking off large pieces of metal.

Screens: Screens may be either of the rotary type or of the vibrating type, and are used principally to get rid of nonmagnetic refuse such as wood wedges, tiles and rags, etc. Rotary-type screens (*Fig.* 6) ordinarily are used where heavy work is encountered, as they have a definite lump-breaking and sand-cooling action. Vibrating screens, as shown in *Fig.* 7, are used where fine sand is required such as in foundries making small castings. It is the usual practice to provide hoods and air suction on these screens for the removal of dust, fines, steam, etc.

Bucket Elevators: Bucket elevators used in the foundry industry are almost always of the centrifugal-discharge belt-and-bucket type, although chain elevators are used infrequently. Malleable buckets are universally used. Foot pulleys are of the slatted type with internal cones so that sand falling inside the belt will not build up on the foot pulley. Boots should have large and readily accessible cleanout doors.

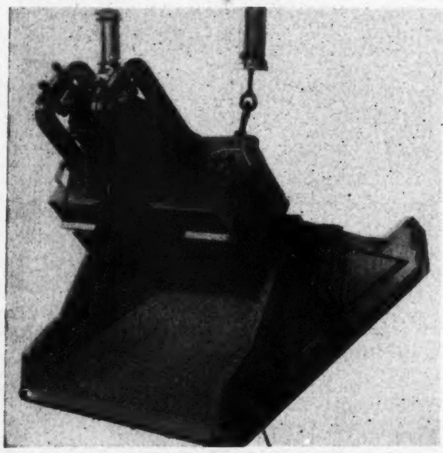


Fig. 7—Left—Vibrating screen is ideal for fine sand used in making the smaller types of castings

Fig. 8—Below—For continuously and automatically filling the molders' hoppers, scraper-type conveyors are employed

Timed Feeders Employed

For feeding sand from the main storage bin to the sand mixers, a method frequently employed uses apron-type feeders for charging the batch-type mixers. The feeders are arranged with either a limit switch or timer so as to operate for a certain number of seconds to give the proper charge. This feeding arrangement will allow for more economical design of bin and one which is much lower in height.

Paddle mixers use the continuous-moving apron feeder almost exclusively. Vibrating feeders or small screw conveyors are used for feeding binders to the mixers.

Distributing System: Flat-belt conveyors with plows are most commonly used for distributing the prepared sand to the molders' hoppers. The belt is supported on flat idlers between the plows and on a flat plate directly under the plows. Plows usually are hinged, employing some simple mechanism for raising or lowering by hand. The part riding the belt should be edged with rubber to prevent injury. Belt cleaners should be installed at the head of this as well as any other belt handling prepared sand.

Mold Conveyors: Layouts for continuous pouring ordinarily utilize continuous-type mold conveyors for receiving the molds at the molding stations and conveying them through the pouring stations to the shakeout. They must be designed so that sufficient cooling time is available from the pouring station to the shakeout. This may vary from as little as 5 minutes for light castings to ½ to 1 hour for larger molds. Air-cylinder pushers frequently are used to push the mold onto the shakeout. The use of a mold conveyor permits the molder to devote practically all of his time to molding, instead of using part of it for carrying out molds to the floor.

Hot-Castings Conveyors: From the shakeout it is necessary to take away the castings and, in the case of smaller castings, this is frequently done with an apron-type hot-castings conveyor. When used for this service, the apron should be of the leakproof type so that sand from the cores, etc., will not be spilled, but will discharge over the head with the castings at one point. For heavier castings, such as cylinder blocks, the overhead-trolley-type conveyor frequently is used, the castings being hooked on the trolley conveyor at the shakeout and frequently carried a considerable distance for cooling purposes.

Flask-Return Conveyors: Flasks must also be returned from the shakeout to the molders and, in the case of smaller work, either the roller-type conveyor, or the overhead-trolley type may be used.

Effective Design Calls for Close Cooperation with User

THROUGHOUT the war innumerable instances have arisen which illustrate the advantages of collaboration between the users of equipment—often military and naval—and the manufacturers. Only through such collaboration have engineers been able to create or refine designs for maximum performance in the field.

It is one thing to develop a design that works without a hitch on demonstration, but an entirely different matter to produce something that performs as well under service conditions. It also is one thing for a designer to satisfy himself, but another to satisfy the customer.

That the effectiveness of collaboration between builder and user is being increasingly recognized is amply demonstrated by recent activities of members of the machine tool industry. After having performed what might well be termed a miracle of production in turning out vast quantities of machine tools during the war, this industry is faced with the problem of an over-saturated market when hostilities cease.

All the government aid or government-sponsored plans that may be proposed are not likely to offer a complete solution to this problem. Instead, machine tool builders feel that the most promising answer is to rely primarily on obsolescence and they are planning to create such a condition through radical redesign. Already several new machine tools capable of revolutionary increased speeds and feeds have made their appearance.

In order to gage clearly the future needs of users, a mass conference recently was held between leaders of the industry and production men from the various plants of General Motors—one of the largest individual users of machine tools. No punches were pulled on either side, the conference thus establishing a clear understanding of what is needed and what can be made available.

The methods adopted by machine tool manufacturers in anticipating their future problems are worthy of note by the entire machinery industry.

L. E. Jermy

Outstanding Designs—

Carried on a slide unit incorporating the V-and-roller principle, the grinding wheel head of Sheffield's thread and form grinder is a self-contained unit having a statically and dynamically balanced motor which is fitted with special mountings to prevent vibration or undue tension on the spindle. The grinding wheel itself is mounted on a wide, tapered-sleeve bearing, the housing of which is carried in a drum which can be adjusted for helix angles up to 20 degrees, either right or left-hand.

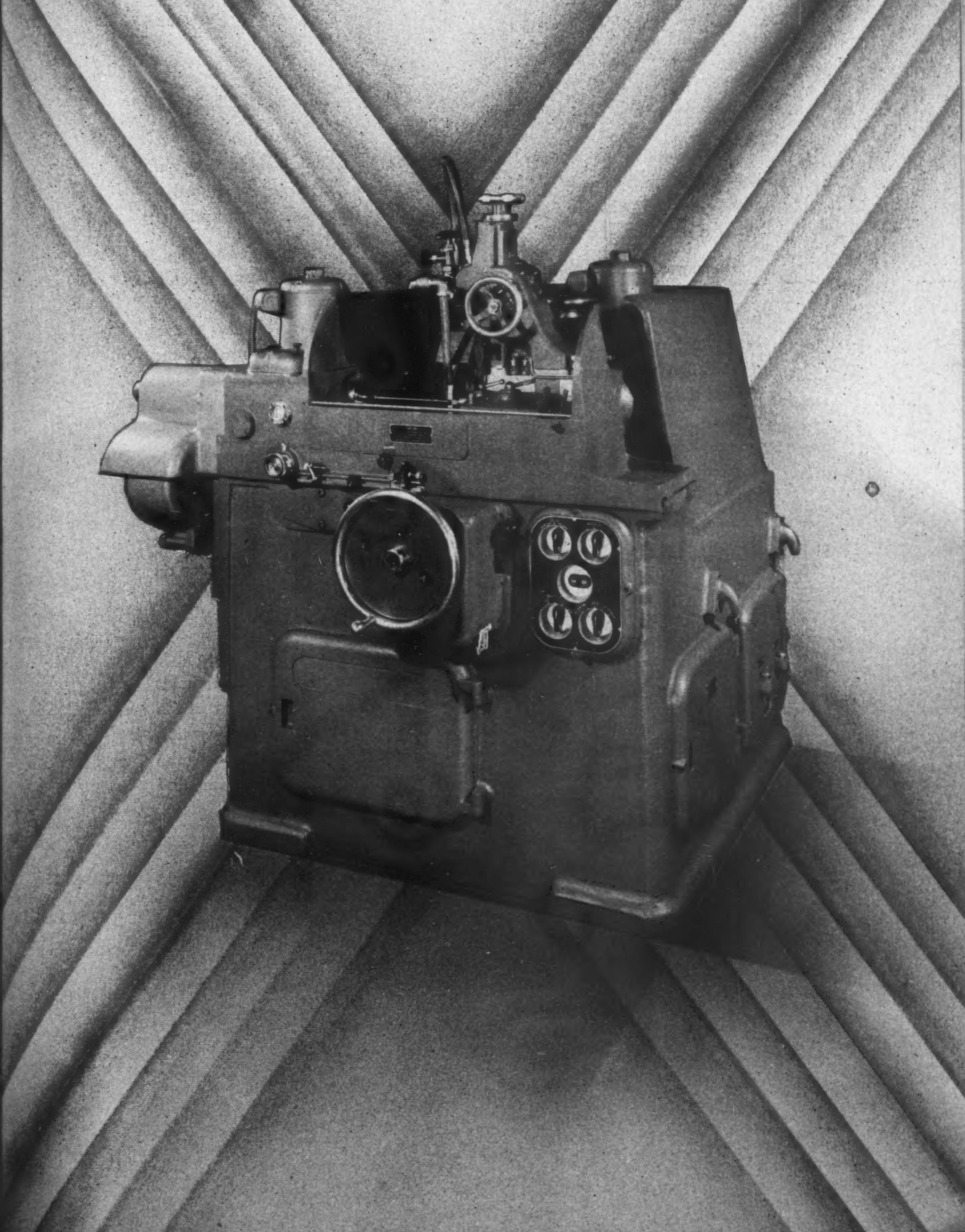
An oil-pressure switch is utilized in the automatic force-feed lubricating system. This switch prevents the wheel motor from starting until the oil pump has built up a predetermined pressure for continuous operation. Sufficient pressure builds up within three to six seconds to automatically switch in the wheelhead motor and, should the oil pressure drop for any reason, the switch immediately stops the entire machine. Separate force-feed lubricating systems are used for the table slides and the spindle.

Consisting of two separate oil reservoirs, a pump for each and a motor which drives both pumps, the oil supply unit is located on the inside of a door in the base of the machine. Flexible lines are utilized to permit opening the door, at which time the unit is readily accessible for inspection or servicing. A closed spindle-lubricating system is employed in which oil passes through a filter as it is pumped to the spindle and the surplus returns to the reservoir. Sight-feed lubricators provide a simple and accurate means of controlling the quantity of oil delivered to the wheel-spindle bearings.

Oil for the table slides, lead and feed screws and nuts and bearings is supplied by another system. In both systems, oil is forced under pressure through adjustable needle valves set to deliver the correct amount of oil. Wheelhead slides and the feed screw are lubricated by oil fed through wicks from a separate hand-filled reservoir. The workhead is lubricated from its own reservoir by means of an oil bath and splash system and the motor drive unit also has its own reservoir.

On the workhead, a vertical motor, statically and dynamically balanced, rotates the work and drives the table through reduction gearing. Change gears provide a complete range of speeds for both work and table.

Precision Thread and Form Grinder



Outstanding Designs—co

Designed to do a complete heat treating job, this combination unit manufactured by the Waltz Furnace Co. has a high-temperature hardening furnace on the left, quench tanks in the center and a recirculating draw furnace on the right.

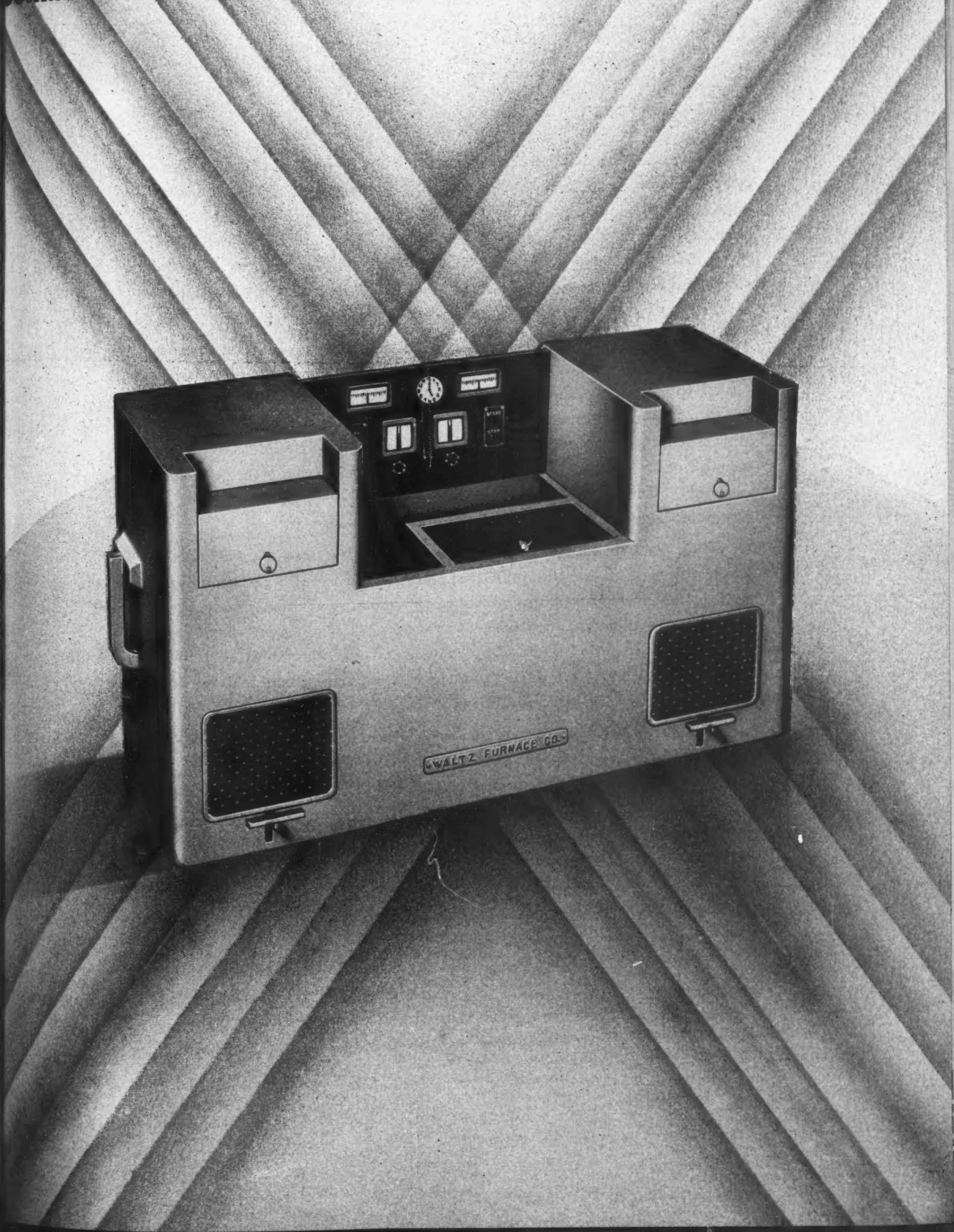
Temperature in the hardening furnace is controlled automatically by an indicating pyrometer that can be hand set to hold any temperature in the range of 1400 to 2350 degrees Fahr. Constant-ratio air-flow mixers feed the burners used for heating. They automatically change air and gas volumes in requisite proportions and are controlled by a single valve. Within the muffle or heating chamber, a protective atmosphere (to prevent scaling and soft skin) can be introduced and is controlled by the two valves located beneath the gages. These gages make it possible to duplicate the atmosphere once the type needed has been established. Efficiency of operation is maintained by seven-inch thick furnace walls made up of 4½ inches of fire brick and 2½ inches of block insulation.

Two quench tanks are in the center of the unit, a small one for oil and a large one for water. Water entirely surrounds the oil tank through double walls. Perforated baskets are used in both tanks.

Temperature range of the recirculating draw furnace is 250 to 1100 degrees Fahr. and is controlled by an automatic indicating pyrometer similar to that employed on the hardening furnace. The interior of the draw furnace is alloy steel around which is cast insulating lining which in turn is protected by an outer shell of steel. Inside the furnace, the hot air for tempering, which is heated by a unit in the base, is recirculated by a high-velocity, alloy-steel fan also located in the base.

Outside shell of the unit is formed-steel, all-welded construction with air grills provided as shown. Foot treadles are used for opening the doors of the furnaces. All equipment necessary for operation is located inside the base and is readily accessible. The unit requires one gas connection and an electric power outlet.

Combination Heat-Treating Furnace



Outstanding Designs—60

Specifications of this most powerful single-acting diesel engine ever built in America are: Normal shaft horsepower, 6000; overload capacity, 10% continuous, 25% for two hours; brake mean effective pressure at 6000 shp rating, 62 psi; speed, 160 rpm; number of cylinders, 9; cylinder bore and stroke, 29-in. by 40-in.; type of engine, 2 cycle, single acting, crosshead; type of fuel-injection system, mechanical; type of scavenging blower, centrifugal motor driven.

Developed and manufactured by Nordberg Mfg. Co., its engine-frame structure consists of a series of cast iron A-frames which rest upon the bedplate and support the cylinder blocks containing the cylinder liners. These A-frames are cored for tie rods which are anchored below and on each side of each main bearing housing in the bedplate to extend through each leg of the A-frames and the cylinder blocks, forming a rigid assembly. The tie rods are tightened with a special hydraulic jack to insure equal stress on all rods and assembled members.

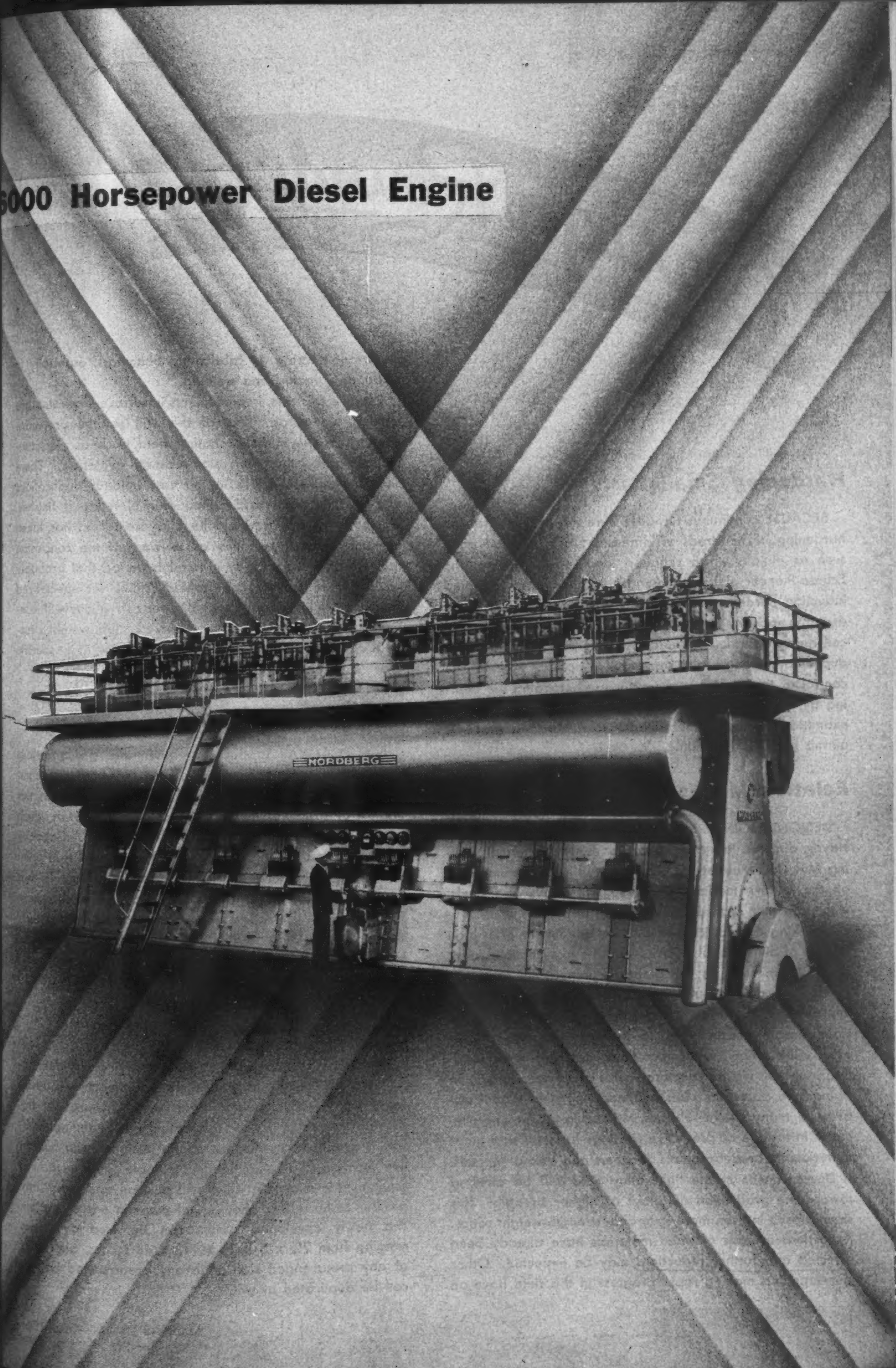
Main and crankpin bearings are removable steel-backed shells lined with special centrifugally cast, antifriction metal. Crosshead-pin bearings are one-piece, copper-base alloy bushings. The cast bedplate is in two sections, bolted together. A crankshaft of two forged sections is employed, one section having five cranks and the other four. Cylinder block or entablature for each cylinder is a separate casting, fitted and bolted to the cylinder blocks adjacent to it.

Automatic plate valves located in the scavenging header and adjacent to the scavenging air ports of each cylinder prevent backflow of exhaust gases and contamination of incoming scavenging air. Scavenging air is furnished by two motor-driven centrifugal blowers which discharge through separate connections to the scavenging header. Pistons are made in two parts; head and skirt. The heads are cooled by circulation of a large quantity of oil at high velocity through cast-in labyrinth passageways. The piston skirt rests upon a flange of the crosshead proper to which it is centered and fastened by cap bolts.

Lubrication is of the pressure-feed type, delivering oil to all working parts of the engine through a large header located in the crankcase with leads to all bearings, camshaft drive and reversing gears.

(For new machines listing see Page 208)

6000 Horsepower Diesel Engine



Design Roundup

Hardening Small Parts

BECAUSE continuous furnaces were not practical for the hardening of hundreds of different types of small parts such as pinions which required localized hardening, the Eclipse-Pioneer division of Bendix Aviation Corp. adapted induction hardening coils to this type of work. The coils are automatically timed to within one-tenth second, special coil being designed for each type of part hardened. Induction annealing is also successfully applied. By a careful control of time and current cycles, and stopping the heating by quenching in an oil bath, certain shaft areas, for example, may be tempered back to a hardness that will permit satisfactory drilling.

Relative Merits of Materials

DESIGN ENGINEERS are in an enviable position, Anson Hayes, director, Research Laboratories, The American Rolling Mill Co., Middletown, O., asserted while commenting on the relative merits of plastics, light alloys and steels, with particular regard to their future applications.

Speaking of plastics, he said the attainment of a high degree of dimensional stability would make possible wider applications, such as refrigerator cabinets, for instance. This could come about in many cases without any great improvement in tension, compression and impact strengths. Considerable improvement in physical properties, however, will be required to place these materials in the load-bearing, light-weight structural fields of service. Reduction in moisture absorption, besides improving dimensional stability in many of the plastics, will bring about improvements in the life of protective coatings for steel and other materials that require paints, lacquers and baked enamels.

Developments in the light alloy field will be directed toward the production of alloys of higher strength. This should result in even more favorable strength-weight ratios. Reductions in costs of these materials have already been effected and further reductions may be expected. Other developments making rapid progress in this field have an important bearing on fabricating behaviors, especially in soldering, brazing and welding.

Relative to steels, improvements in surface protection are coming along fast. Out of this will emerge protective coatings in the metallic coating field, such as zinc, aluminum and other corrosion-resistant materials. There should be great strides in the vast field of applications of paints, lacquers and baked enamel types of finishes. The progress achieved by the alloy-steel field has taken on such great importance as to warrant the conclusion that industry has already entered a period that probably could be called that of "special steels for specialized uses". New high-strength and lower-cost alloys will continue to compete for the market in the light-weight structural field and will continue to offset the high specific gravity disadvantages of steel.

Use Magnesium on Cost Basis?

FOR POSTWAR products, designers are giving serious attention to utilization of magnesium for machine components. In the space of three years, applications of this lightest of structural metals has achieved a growth which would have taken many years in peacetime. Capacity for casting and forging the metal has expanded to a point which will be in excess of normal demand, indicating that a strong effort will be made to develop new applications. The competitive situation, plus more economical production procedure sure to come, may influence price to an extent that magnesium will be able to compete with other construction materials on a comparatively favorable basis.

Stampings Improve Position

ONE EFFECT which wartime manufacturing will definitely have on design of peacetime equipment will result from improved technique on flat metal assemblies. Improved knowledge of both fabricating and fastening methods is available for the use of the designer who has an eye on costs. For example, multiple hole punching equipment is available which will position and punch any number of holes in a sheet-metal piece in one operation. This newly developed system can be used on pieces ranging from 2½ x 5 inchs to 43 x 48 inches, and holes of any prearranged size or in any prearranged pattern can be duplicated at will.

Calculating Weights of Fillet Sections

By Clifford H. McClain

FILLET sections most frequently encountered may be reduced to two simple types illustrated in *Fig.* 1. The concave fillet shown at left of the figure is the more common. The convex fillet shown at the right is not a fillet in the true sense but it may be considered so for the purpose of this discussion.

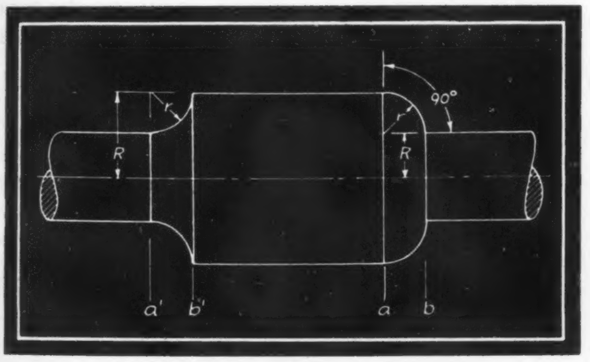


Fig. 1—Above—Concave and convex fillet sections

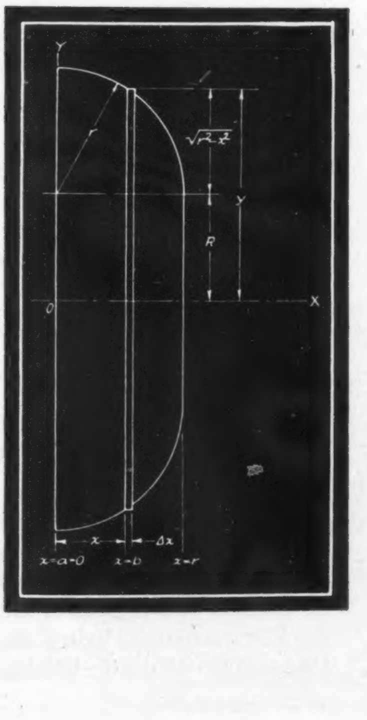


Fig. 2 — Right — Volume of convex fillet section is sum of all individual disks or slices making up entire section

In order best to analyze the geometry of the two fillet sections it is necessary to plot them on coordinate axes and consider them as solids of revolution. A typical convex fillet section is plotted in *Fig.* 2. Here R represents the distance between the center of the shaft and the radius point of the fillet arc, while r is the fillet radius. Assume that the entire fillet section is composed of a number of thin disks or slices each with

IN ESTIMATING THE WEIGHT of large shafts, coupling flanges, flywheels and similar objects it is necessary, when accuracy is desired, to find the volume of those sections that are in the form of circular fillets. Because standard reference books do not, as a rule, include suitable formulas for calculating volumes of this nature, the equations in this data sheet have been derived and may be applied in such calculations

a different radius and each of thickness Δx. The volume of any cylinder is equal to the circular area multiplied by the length. Volume of one disk, for example, would be

$$\Delta V = \pi y^2 \Delta x \qquad (1)$$

and total volume the sum of all the disks making up the entire fillet section. Accuracy of the volume thus found depends, of course, on the size selected for Δx.

Since the fillet arc follows the equation of a circle, y is a function of x and may be so expressed:

$$y=R+\sqrt{r^2-x^2} \quad \ldots\ldots \quad (2)$$

In the limit when Δx tends toward zero, Equation 1 then becomes, on summation,

$$V=\int_a^b \pi(R+\sqrt{r^2-x^2})^2 dx \quad \ldots\ldots \quad (3)$$

Expanding and integrating,

Fig. 3—Right—Concave fillet section volume is calculated by summing those of the slices making up the section

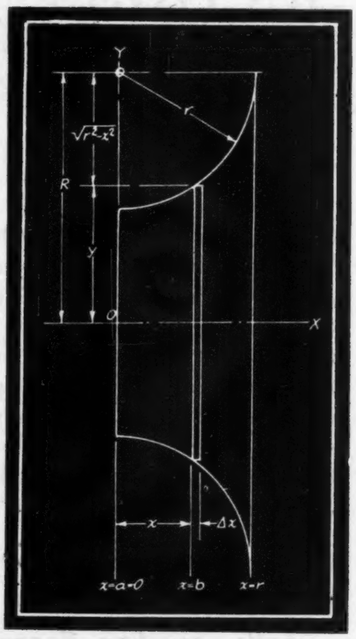
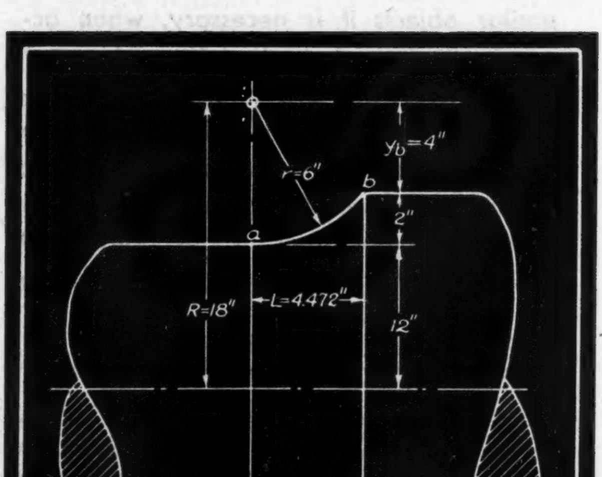


Fig. 4—Below—Calculation of volume of a fillet section with an arc less than 90 degrees involves determination of length L



$$V=\pi\left[R^2x+R\left(x\sqrt{r^2-x^2}+r^2\sin^{-1}\frac{x}{r}\right)+r^2x-\frac{x^3}{3}\right]_a^b \quad (4)$$

where a and b represent any assigned values of x between $x=0$ and $x=r$. When $a=0$ and $b=r$ as in the case of a fillet with a 90-degree arc, Equation 4 may be simplified to the form

$$V=\pi(R^2r+1.5708Rr^2+.6667r^3) \quad \ldots\ldots \quad (5)$$

The same reasoning may be applied to the concave fillet section plotted in *Fig.* 3. From the geometry of the figure it is evident that

$$V=\int_a^b \pi(R-\sqrt{r^2-x^2})^2 dx \quad \ldots\ldots \quad (6)$$

Expanding and integrating,

$$V=\pi\left[R^2x-R\left(x\sqrt{r^2-x^2}+r^2\sin^{-1}\frac{x}{r}\right)+r^2x-\frac{x^3}{3}\right]_a^b \quad (7)$$

In the case of a 90-degree fillet arc when $a=0$ and $b=r$, Equation 7 is simplified to

$$V=\pi(R^2r-1.5708Rr^2+.6667r^3) \quad \ldots\ldots \quad (8)$$

Example 1: It is required to find the weight of the convex fillet section *a-b Fig.* 1, including the solid shaft beneath the fillet, when $R=6$ inches, $r=2$ inches and the angle of the fillet arc $=90$ degrees.

Numerical substitution in Equation 5 gives

$$V=3.1416(6^2\times2+1.5708\times6\times2^2+.6667\times2^3)$$

$$=361.39 \text{ cubic inches}$$

Assuming the shaft is of steel weighing .282 pounds per cubic inch, the weight of the section is $361.39\times .282=101.91$ pounds.

Example 2: It is required to find the weight of the concave fillet section *a-b*, including the solid shaft beneath the fillet, shown in *Fig.* 4. The shaft is made of cast iron weighing .26 pounds per cubic inch.

Since the fillet arc in this case is less than 90 degrees it is necessary first to find the numerical value of x at point b on the arc when $y_b=4$ inches.

Denoting this value by L, then

$$L=\sqrt{r^2-y_b^2}=\sqrt{6^2-4^2}=4.472 \text{ inches}$$

Substituting numerical values in Equation 7,

$$V=3.1416\left[18^2\times4.472-18\left(4.472\sqrt{6^2-4.472^2}+6^2\sin^{-1}\frac{4.472}{6}\right)+6^2\times4.472-\frac{4.472^3}{3}\right]_0^{4.472}$$

$$=2240.45 \text{ cubic inches}$$

In this calculation, the sine is $4.472/6=.7453$, hence the angle is 48.2 degrees or .81 radians. The weight of the fillet section, including the solid shaft beneath the fillet is $2240.45\times.26=582.52$ pounds.

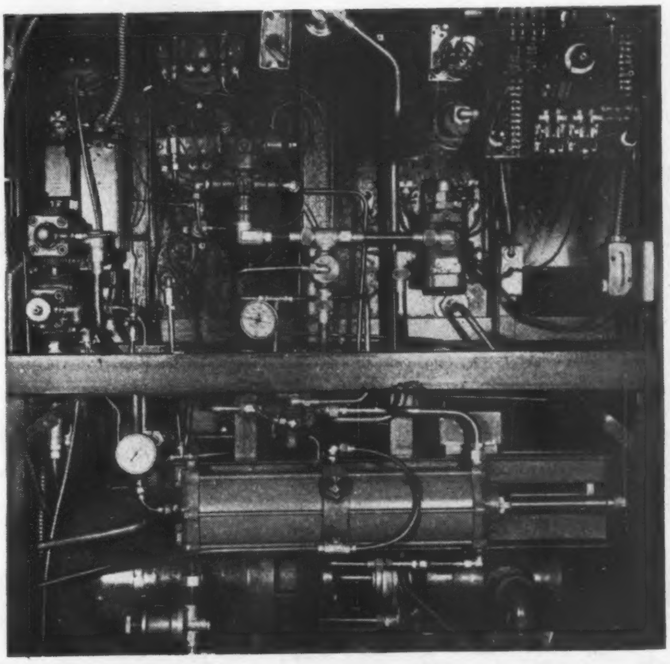
Applications

of Engineering Parts, Materials and Processes

Fluid System Pinch-Hits for Propeller

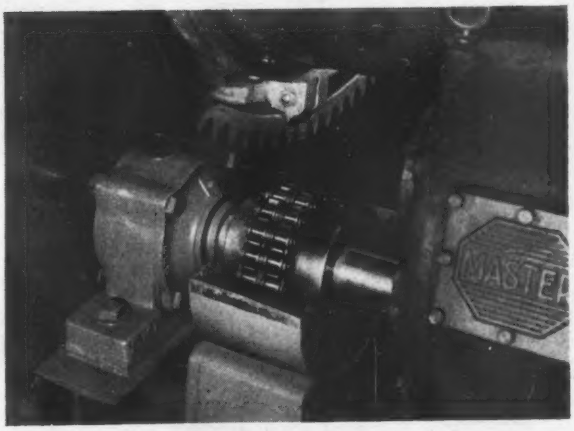
Developed for testing airplane propeller governors, the Nash-Kelvinator machine shown at right employs a Vickers pressure oil system to serve as a "dummy propeller". The governor is driven by an electronically controlled motor and, since it functions hydraulically, regulates the pressure in the system, thereby controlling the speed of the driving motor.

Speed is measured to an accuracy within one revolution per minute by observing the frequency of current output of an alternating-current generator hooked up to the driving motor. Governor performance is checked by comparison on two identical dials with a "time yardstick" which is accurate to within one ten-thousandth of a second.



Flexible Coupling for Dryer Drive

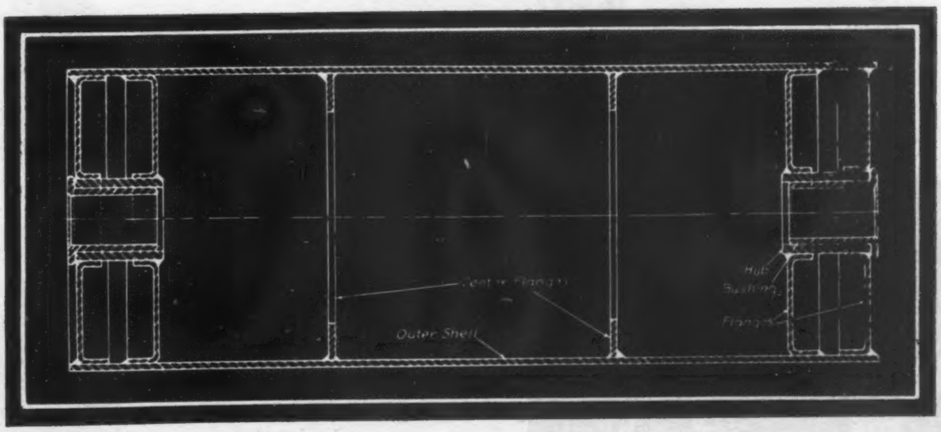
Power drive to the Hetherington-Berner sand and gravel dryer shown at right center is transmitted through a Diamond Chain flexible coupling connecting the 25-horsepower gear motor to the 43-revolutions per minute pinion. Use of a double chain in the coupling provides large roller-sprocket bearing area for high capacity and permits boring for large shafts. Clearance between the sprockets and the chain sideplates allows freedom of movement so that coupling can adjust itself to angular misalignment or deflection and can provide end play.

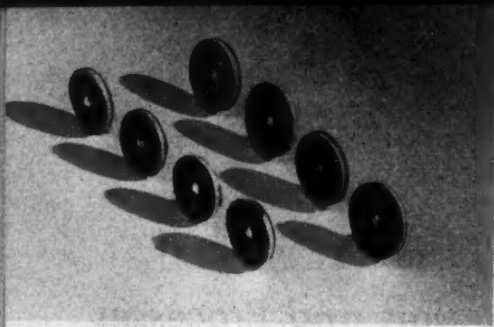


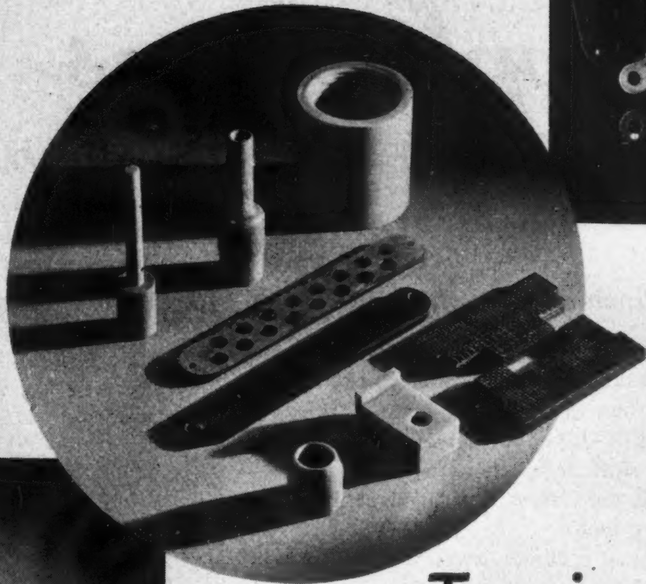
Welded Design Cuts Costs

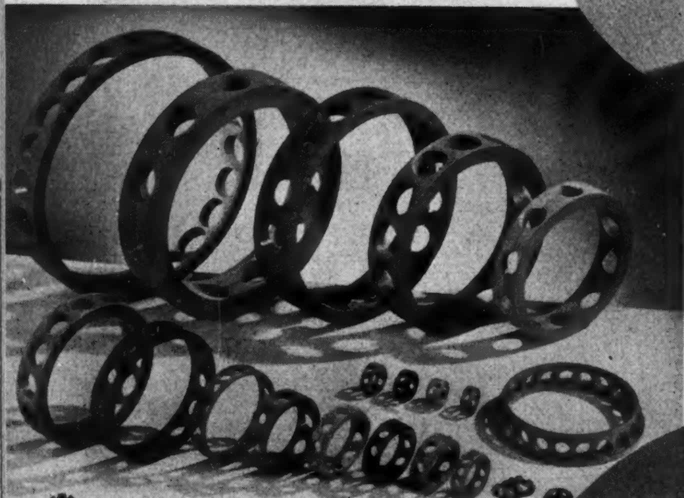
End pieces on the 12-inch diameter roller shown at right below formerly were cast or forged parts. Redesigned by Cleveland Welding Co., the roller employs all-welded construction, effecting substantial savings in cost, production time and manufacturing facilities. The roller is used on an application where it must withstand the full impact of heavy vehicles striking trees, ditch walls and other obstacles, thus requiring toughness as well as high strength.

In the entire job the only machining involved is a reaming operation on the inside diameter of the hub into which the bearing bushing is pressed. Outside diameter of the shell is held within plus or minus 1/32-inch with maximum runout not exceeding 1/8-inch.

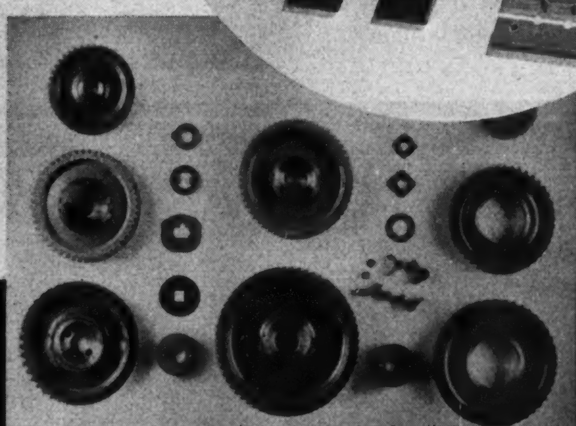








Typical Laminated Phenolic Parts



Materials Work Sheet

Filing Number **17.01**

Laminated Phenolic Plastics

ASTM Grades C, CE, L, LE and AA (Fabric Base)

AVAILABLE IN:

(Grade C)	Sheets, rolled tubes, molded rods
(Grade CE)	Sheets, molded tubes, molded rods
(Grade L)	Sheets, molded tubes, molded rods
(Grade LE)	Sheets, rolled and molded tubes, molded rods
(Grade AA)	Sheets, rolled and molded tubes, molded rods

Note: All grades also are available in molded shapes and with the exception of Grade AA in the form of machined rods. These, however, are not covered by A.S.T.M. specifications.

PHYSICAL AND ELECTRICAL PROPERTIES

TENSILE STRENGTH*
(1000 *psi—min*)

	Grades				
	C	CE	L	LE	AA
Sheet, 1/16 to 1-in. thk.	7.5	6.5	7	6.5	6
Tubing, rolled	5.5	...	...	5	...
molded	...	6.5	6.5	6	...
Rod, molded					
3/16 to 1/4-in. diam.	...	...	8	6	...
Over 1/4 to 1/2-in. diam.	7.5	6.5	8	6	...
Over 1/2 to 1-in. diam.	8	7	8	6	...
Over 1 to 2 in. diam.	6.5	6	6.5	4.8	...

FLEXURAL STRENGTH*
(1000 *psi—min*)

	Grades				
	C	CE	L	LE	AA
Sheet, 1/16 to 1-in. thk.	16	13	15	15	15
Rod, molded					
3/16 to 1/4-in. diam.	..	..	16	12	..
Over 1/4 to 1/2-in. diam.	17	12	16	12	..
Over 1/2 to 1-in. diam.	17	14	16	12	..
Over 1 to 2 in. diam.	14	12	13	9	..

IZOD IMPACT STRENGTH
(*ft-lb per in.—min*)

	Grades				
	C	CE	L	LE	AA
Sheet, machined to ½-in. thk. loaded flatwise	3.2	2.3	2.5	1.8	..
Sheet, loaded edgewise	2.0	1.3	1.2	1.0	..

CHARPY IMPACT STRENGTH†
(*unnotched, min—ft-lb per in.*)

	Grades				
	C	CE	L	LE	AA
(Specimen ½-in. thk.)					
Sheet, loaded flatwise	12.5	10.6	8.8	7.9	9.2
Sheet, loaded edgewise	9.4	8	7.3	6.3	6.8

MACHINE DESIGN is pleased to acknowledge the collaboration of the following companies in this presentation: The Formica Insulation Co.; St. Regis Paper Co.; Synthane Corp.; Westinghouse Electric & Mfg. Co. Photos on opposite page appear through courtesy of Bakelite Corp.

*Minimum values for sheets 1 to 2 inches thick will range 10 per cent lower than values listed. Unless otherwise noted, values listed conform to ASTM Spec. D709-43T.

†Values supplied by Westinghouse Electric & Mfg. Co.

COMPRESSIVE STRENGTH*
(1000 *psi—min*)

	Grades				
	C	CE	L	LE	AA
Sheet, 1/16 to 1-in. thk. loaded flatwise	35	34	30	33	35
Tubing, rolled, axial load	11	..	..	11	..
molded, axial load	..	19	18	19	..
Rod, molded, axial load					
3/16 to ¼-in. diam	..	..	20	21	..
Over ¼ to ½-in. diam	20	21	20	21	..
Over ½ to 1-in. diam	20	21	20	21	..
Over 1 to 2 in. diam	20	21	20	21	..

MODULUS OF ELASTICITY†
(*average—times* 10^5)

	Grades				
	C	CE	L	LE	AA
Sheet, loaded edgewise 90 deg to fiber warp	5.4	..	6.6	6.3	12.8
Sheet, loaded edgewise parallel to fiber warp	8.1	..	9.4	8.8	13.2

Values based on stress-strain diagram showing tensile stress against corresponding elongation.

WATER ABSORPTION
(*after 24-hrs immersion—max per cent*)

	Grades				
	C	CE	L	LE	AA
Sheet 1/32-in. thk.	..	..	6	3.6	..
1/16-in. thk.	4.4	1.8	2.5	1.8	1.9
3/32-in. thk.	3.2	1.5	1.9	1.5	1.5
⅛-in. thk.	2.5	1.4	1.6	1.25	.95
3/16-in. thk.	1.9	1.2	1.3	1.0	.8
¼-in. thk.	1.6	1.0	1.1	.9	.7
½-in. thk.	1.2	.7	.8	.65	.55
¾-in. thk.	1.1	.65	.75	.6	.5
1-in. and over	1.0	.6	.7	.55	.45
Tubing, rolled					
1-in.I.D. by 1¼-in.O.D.	3	..	..	2.5	..
1-in.I.D. by 1⅛-in.O.D.	..	..	..	4.5	..
Tubing, molded					
1-in.I.D. by 1¼-in.O.D.	..	1.5	1.75	1.1	..
1-in.I.D. by 1⅛-in.O.D.	..	..	3.5	2.2	..
Rods, molded					
¼ to ½-in. diam	2.5	1.5	1.5	1.2	..
½ to 1-in. diam	2.0	1.0	1.2	.9	..
2 in. diam	1.5	1.2	1.2	1.1	..

Materials Work Sheet

AVERAGE HARDNESS†

(Rockwell M—1/4 ball—100 kg)

	Grades C	CE	L	LE	AA
Flatwise	102	108	106	113	106
Edgewise	97	101	99	106	102

POWER FACTOR, DIELECTRIC CONSTANT AND LOSS FACTORS §

(at 10^6 cycles—max)

	Grades CE	LE
Power Factor		
Sheet, 1/16 to 1-in. thk. ..	.065	.055
Dielectric Constant		
Sheet, 1/16 to 1-in. thk. ..	6.0	5.5
Loss Factor		
Sheet, 1/16 to 1-in. thk. ..	.4	.3

DIELECTRIC STRENGTH §

(in oil at room temp—volts per mil—min)

Sheet Thickness (inches)	Grade CE: Short-Time Test	Grade CE: Step-by-Step Test	Grade LE: Short-Time Test	Grade LE: Step-by-Step Test
.015 to 1/32	...	...	560	350
Over 1/32 to 1/16.	400	240	400	240
Over 1/16 to 1/8..	290	170	290	170
Over 1/8 to 1/4...	200	120	200	120
Over 1/4 to 1/2...	145	85	145	85
Over 1/2 to 3/4...	120	70	120	70
Over 3/4 to 1.....	105	60	105	60
Over 1 to 2.......	75	40	75	40

§Grades C, L and AA are not intended for any but low-voltage electrical applications, being compounded more specifically for mechanical purposes. Dielectric strength values conform to 1939 N.E.M.A. standards.

OTHER PROPERTIES

	Grades C	CE	L	LE	AA
Weight (lb. per cu. in.)	.0498	.0498	.0491	.0487	.065
Specific Gravity	1.38	1.38	1.36	1.35	1.8

CHARACTERISTICS

Grade C: Having best mechanical properties, it is a strong, tough material, suitable for gears and other applications requiring high impact strength. It is not satisfactory for any but low-voltage electrical applications. Has good bond strength, good resistance to splitting and fair resistance to moisture.

This material is a heavy-weave fabric-base laminate made from cotton fabric weighing over 4 ounces per square yard and having a count as determined from inspection of the laminated plate of not more than 72 threads per inch in the filler direction, nor more than 140 threads per inch total in both warp and filler directions. Semigloss finish on molded surfaces.

Grade CE: For electrical applications requiring greater toughness than that offered by paper-base Grade XX, or mechanical applications requiring greater resistance to moisture than that afforded by Grade C. Has good machinability. Its mechanical properties, however, are below those of Grade C. It is a heavy-weave, fabric-base laminate of the same fabric weight and thread count as Grade C. Semigloss finish.

Grade L: Has good mechanical properties. Not quite as tough as Grade C but has somewhat better resistance to moisture absorption. Is suitable for small gears and similar fine machining applications, particularly in thicknesses under 1/2 inch. Should not be used for electrical applications except for low voltage. It is a fine-weave fabric-base laminate made throughout from cotton fabric weighing 4 ounces or less per square yard. The minimum thread count per inch in any ply is 72 in the filler direction and 140 total in both warp and filler directions. Semigloss finish on molded surfaces.

Grade LE: For electrical applications requiring greater toughness than that offered by paper-base Grade XX. Has lower power factor, better machining properties and finer appearance than Grade CE, and is available in thinner sizes. Good resistance to moisture. It is a fine-weave fabric-base laminate of the same fabric weight and thread count as Grade L. Semigloss finish on molded surfaces.

Grade AA: Asbestos fabric-base laminate. Has more resistance to flame and slightly higher resistance to heat than others except the asbestos paper-base Grade A. However, it is stronger than Grade A. Temperature limitation is about 150 to 175 degrees Cent. for short intermittent applications of heat. Higher temperatures cause blistering and result in eventual loss of mechanical strength. At room temperature, its mechanical properties are equal to or slightly lower than those of the best cloth-base grade. Has fair resistance to splitting and good resistance to moisture. Its dielectric properties are poor. Semigloss finish on molded surfaces.

APPLICATIONS

Grade C: For parts requiring high strength and toughness. Typical parts are gears and pinions having teeth larger than 24 pitch, cams, rollers and similar items subject to difficult machining.

Grade CE: Electrical applications which demand toughness and high impact. Typical: Marine control panels. Also for mechanical applications which require good moisture resistance and good machinability.

Grade L: For shapes requiring a good deal of machining and having thin wall sections. For gears and pinions having teeth smaller than 24 pitch and other mechanical applications which require threading and a finer appearance than is offered by Grades C and CE. Use for only low-voltage electrical applications under dry conditions.

Grade LE: Good for general electrical applications which demand toughness in combination with good appearance. For electrical parts which require threading and extensive machining.

Grade AA: Used for armature slot wedges in railway and mill motors. For parts in machines where heat is a factor and which require Class B insulation for low voltage. Suitable for high-temperature mechanical applications requiring good strength at temperatures where the binder will oxidize and heat resistance will remain. Confine to parts requiring only simple machining and avoid applications and machining operations which set up splitting stresses.

FABRICATION

MACHINABILITY:

All five grades are machinable by milling, sawing, turning, drilling, reaming and shaping. Thicknesses up to 1/16 and 1/8-inch, depending on the grade, may be sheared and punched. Heavier thicknesses may be shaved, sanded or ground. In general, they are machined more readily than metals. Overheating of the material during machining should be avoided. For punching and shearing, the material usually is heated to from 100 to 120 degrees Cent. Slower machining speeds are recommended for Grade A than for the others. Cutting compounds or lubrication are unnecessary.

TURNING:

Cutter speeds and feeds usually are high. Generally recommended are surface speeds ranging from 200 to 2000 feet per minute, the rate being determined by the finish desired. Tungsten-carbide-tipped tools are used for high-speed machining. Since destructive chattering is not produced in machining these materials, carbide tools can be used for discontinuous cuts. Tools are ground to greater clearances than for machining metals and are set on or slightly below the center of the work. Threads are cut on the lathe rather than with a die, and a two-thirds thread is most desirable.

MILLING:

Cutter speeds ranging from 400 to 1500 feet per minute in conjunction with rapid feeds are used in milling, with due caution being exercised to avoid excessive heat-up. For high production, carbide-tipped cutters are recommended. As in turning, the tools are afforded greater clearances than for cutting metals. Metal backing-up fixtures are used on the work to prevent burred edges. To guard against scuffing and chipping when milling flat at a small angle to the laminations, the feed is down through the laminations rather than up. End milling effects better finishes than are procurable by means of radial milling.

DRILLING, TAPPING AND REAMING:

200 to 400 feet per minute peripheral speed is recommended. As in milling and turning, greater clearances are provided and drill tips are ground to a sharp angle of approximately 30 degrees to the rotation axis. It is desirable to have one tip do most of the cutting. Drills are lifted frequently when drilling deep holes to remove chips and prevent overheating. Material is backed up to prevent pushing through with attendant burring. Drilling, tapping and reaming parallel to the laminations are done carefully to avoid splitting and the parts are clamped firmly in a vise. Large holes in thin sheets can be fly-cut in a drill press.

To permit the tool to find its own center, reaming and tapping are done with either a floating chuck or a floating vise. Low speeds and high feeds are used for reaming. Holes for tapping are chamfered for clean starting of the tap and of such size as to produce a two-thirds thread. Self-tapping screws are used readily except in applications where the holes are parallel to the laminations.

SAWING:

Best results are achieved with hollow-ground saws of 14-inch diameter with four teeth per inch operating at 10,000 to 13,000 feet per minute peripheral speed. Since dull saws burn and chip the material, care is taken to keep saws sharp. Sheets 1 inch and less in thickness are best cut on circular saws while thicker sheets are handled most efficiently on band saws. Fine-toothed saws, having six to eight teeth per inch are used for sheets 1/16-inch and less in thickness. Good results in band sawing are achieved with regular set saws having five or six teeth per inch and run at 3000 to 5000 feet per minute. Sharp contour work requires narrow blades, while for faster cutting and better control, broad blades are used.

SHEARING:

Thin sheets are sheared with a knife edge having less rake than is used for metal—one inch in five feet being recommended. Shearing properties of the harder grades are improved by heating. For hot shearing, temperatures of from 100 to 120 degrees Cent. are recommended. Too long an exposure to higher temperatures will cause brittleness. The following is a general guide showing the approximate thickness limits for shearing:

Materials Work Sheet

Grade	Maximum Thickness (inches) Sheared Cold	Sheared Hot
C	1/16	3/16
CE	1/32	3/32
L	1/16	3/16
LE	1/32	3/32
AA	1/32	1/16

PUNCHING:

All grades except AA are suitable for cold or hot punching. Dies, which must be kept sharp, are the same as for punching metal except that clearances between punch and die are smaller. A hot-punched hole or blank will shrink slightly as it cools to room temperature and allowance must be made for this shrinkage. For precision holes, stock may be left on the diameter for finish drilling. In general, specify holes no smaller in diameter than the thickness of the material. A good rule to follow when laying out holes, is to make the distance between the holes and the edge of the sheet not less than the sheet thickness. Also the holes should be separated from each other by at least the sheet thickness. The temperature for hot punching is the same as that used for hot shearing, i.e., 100 to 120 degrees Cent. The following is a general guide indicating the thickness limits for cold and hot punching of sheet stock:

Grade	Maximum Thickness (inches) Punched Cold	Punched Hot
CE	1/16	3/16
L	1/16	3/32
LE	1/16	3/16
C	1/16	3/32
AA (simple shapes only)	1/32	1/16

CORROSION RESISTANCE

Salts: Generally speaking, any concentration and temperatures up to 180 degrees Fahr. of the salts of the following metals will not affect these laminates except for a slight change of color:

Aluminum	Lead
Ammonium	Magnesium
Barium	Manganese
Bismuth	Nickel
Cadmium	Silver
Cobalt	Tin
Copper	Zinc
Iron	Mercury

Calcium (except hypochlorite)
Potassium (except hydroxide)
Sodium (except hydroxide and hypochlorite)

Solvents: They will also resist the following solvents:

Alpiphatic Hydrocarbons
Aromatic Hydrocarbons
Chlorinated Hydrocarbons, except those which have hydrolysed; for example:
Carbon Tetrachloride in the presence of moisture
Ketones at room temperature
Alcohols, esters and ethers

They will not resist:

Chlorine Gas, wet or dry	Potassium Hydroxide
Sodium Hypochlorite	Calcium Hypochlorite
Chlorine Water	Bromine and Bromine Water
Sodium Hydroxide	Pyridine

Materials Work Sheet

CORROSION RESISTANCE

(cont'd.)

Acids: They will resist the following acids at the concentrations noted:

Glacial Acetic (special resin)	Citric Conc.	Oleic 5%
Benzonic Conc.	Formic Conc.	Oxalic Conc.
Boric Conc.	Hydrochloric 10%	Phosphoric 10%
Phenol 10%	Hydrofluoric 20%	Sulphuric 15%
Chromic 45% (spec. resin; intermittent exposure)	Lactic Conc.	Sulphurous 6%
	Nitric 2%	

Note: The addition of salts such as 20 per cent sodium sulphate to 10 per cent sulphuric acid is known to inhibit the effect of the acid for a long period of time. A mixture of sodium hydroxide 10 per cent and sodium cyanide 10 per cent also shows this phenomena. This concentration of sodium hydroxide alone would rapidly attack the laminate.

MATERIAL DESIGNATIONS

ASTM	NEMA	Navy Grade Spec. 17P5	Army Grade Spec. 71-484	Federal Grade Spec. HH-P-256
C	C	FBM	C	C
CE	CE	FBG		CE
L	L	FBI		L
LE	LE	FBE		LE
AA	AA	FBH		AA

DATA ON STOCK FORMS

Plate

STANDARD THICKNESS TOLERANCES (inches)‡

Nominal Thickness (inches)	Grades: C Plus or Minus	CE Plus or Minus	L Plus or Minus	LE Plus or Minus	AA Plus or Minus
.010	....	....	.003	....	....
.015	....	....	.0035	.0035	....
.020	....	....	.004	.004	....
.025	....	....	.0045	.0045	....
1/32	.0065	.0065	.005	.005	....
3/64	.0075	.0075	.0055	.0055	....
1/16	.0075	.0075	.006	.006	.018
3/32	.009	.009	.007	.007	.018
1/8	.010	.010	.008	.008	.020
5/32	.011	.011	.009	.009	....
3/16	.0125	.0125	.010	.010	.024
7/32	.014	.014	.011	.011	....
	Plus only	Plus or Minus	Plus only	Plus or Minus	Plus or Minus
¼	.030	.015	.024	.012	.028
5/16	.035	.0175	.029	.0145	.034
⅜	.040	.020	.034	.017	.038
7/16	.044	.022	.038	.019	.044
½	.048	.024	.042	.021	.048
⅝	.053	.027	.048	.024	.058
¾	.058	.029	.054	.027	.068
⅞	.062	.031	.060	.030	.076
1	.065	.033	.065	.033	.086

Plate

Over 2 to 10 Inches Thick

STANDARD THICKNESS TOLERANCES (inches)‡

Nominal Thickness (inches)	Grade C Plus only	Nominal Thickness (inches)	Grade C Plus only
2¼	.105	6	.23
2½	.113	6½	.24
2¾	.121	7	.26
3	.130	7½	.28
3½	.146	8	.29
4	.163	8½	.31
4½	.179	9	.32
5	.190	9½	.34
5½	.210	10	.36

‡1939 N.E.M.A. standards.

Number of Feet of Tube in One Pound

I.D. (inches)	Thickness of Wall (inches): 1/32	1/16	3/32	⅛	5/32	3/16	7/32	¼	9/32	5/16	11/32	⅜
⅛	102.40	42.66	24.38	16.00	.....	.....	.....	.....	....	....	....	....
3/16	73.14	32.00	18.96	12.80	.....	.....	.....	.....	....	....	....	....
¼	56.88	25.60	15.51	10.66	7.877	6.095	.....	.....	....	....	....	....
5/16	46.54	21.33	13.12	9.143	6.826	5.333	.....	.....	....	....	....	....
⅜	39.38	18.28	11.37	8.000	6.023	4.740	.....	.....	....	....	....	....
7/16	34.13	16.00	10.03	7.111	5.389	4.266	.....	.....	....	....	....	....
½	30.11	14.22	8.982	6.400	4.876	3.871	3.180	2.666	....	....	....	....
9/16	26.94	12.80	8.127	5.818	4.452	3.555	2.925	2.461	....	....	....	....
⅝	24.38	11.63	7.420	5.333	4.096	3.282	2.708	2.285	....	....	....	....
11/16	22.26	10.66	6.826	4.923	3.792	3.047	2.522	2.133	....	....	....	....
¾	20.48	9.846	6.321	4.571	3.531	2.844	2.359	2.000	....	....	....	....
13/16	18.96	9.143	5.885	4.266	3.303	2.666	2.216	1.882	....	....	....	....
⅞	17.65	8.533	5.505	4.000	3.103	2.509	2.089	1.777	....	....	....	....
15/16	16.51	8.000	5.171	3.764	2.925	2.370	1.976	1.684	....	....	....	....
1	15.51	7.529	4.876	3.555	2.767	2.245	1.875	1.600	....	....	....	....
1⅛	13.83	6.737	4.376	3.200	2.496	2.031	1.700	1.454	....	....	....	....
1¼	12.48	6.095	3.969	2.908	2.275	1.855	1.556	1.332	....	....	....	....
1⅜	11.37	5.565	3.630	2.665	2.090	1.706	1.434	1.230	....	....	....	....
1½	10.44	5.200	3.345	2.461	1.932	1.580	1.330	1.142	....	....	....	....
1⅝	9.660	4.740	3.103	2.285	1.796	1.471	1.239	1.066	....	....	....	....
1¾	8.982	4.413	2.891	2.132	1.678	1.376	1.160	1.000	....	....	....	....
1⅞	8.393	4.130	2.708	2.000	1.575	1.292	1.091	.941	....	....	....	....
2	7.877	3.878	2.547	1.882	1.483	1.219	1.030	.889	.773	.692	....	....
2⅛	7.420	3.656	2.403	1.777	1.402	1.152	.975	.842	.739	.656	....	....
2¼	7.013	3.459	2.274	1.684	1.330	1.094	.926	.800	.702	.624	....	....
2⅜	6.649	3.282	2.160	1.600	1.264	1.040	.881	.762	.669	.596	....	....
2½	6.321	3.121	2.055	1.523	1.204	.992	.841	.727	.639	.569	....	....
2⅝	6.023	2.976	1.961	1.454	1.150	.948	.804	.696	.612	.545	....	....
2¾	5.752	2.844	1.875	1.391	1.101	.908	.770	.667	.587	.522	....	....
2⅞	5.505	2.722	1.796	1.333	1.055	.871	.739	.640	.563	.502	....	....
3	5.278	2.611	1.723	1.280	1.013	.837	.710	.615	.542	.483	.435	.395
3⅛	5.069	2.509	1.656	1.231	.994	.805	.683	.593	.522	.465	.419	.381
3¼	4.876	2.414	1.595	1.185	.936	.776	.659	.572	.504	.449	.405	.368
3⅜	4.697	2.326	1.543	1.143	.906	.749	.636	.552	.486	.434	.391	.355
3½	4.531	2.245	1.483	1.103	.857	.724	.615	.534	.471	.420	.378	.344
3⅝	4.376	2.169	1.434	1.066	.846	.700	.595	.516	.455	.406	.366	.333
3¾	4.231	2.097	1.387	1.032	.819	.677	.576	.500	.441	.394	.355	.323
3⅞	4.096	2.031	1.343	1.000	.794	.656	.558	.485	.428	.382	.345	.314
4	3.969	1.968	1.302	.970	.770	.637	.542	.470	.415	.371	.335	.305

MATERIAL TRADENAMES

Tradenames	Producers
Dilecto	Continental-Diamond Fibre Co.
Farlite	Farlite Division Farley & Loetscher Mfg. Co.
Formica	Formica Insulation Co.
Textolite	General Electric Co.
Lamicoid	Mica Insulator Co.
Phenolite	Phenolite Division National Vulcanized Fibre Co.
Panelyte	Panelyte Division St. Regis Paper Co.
Insurok	Richardson Co.
Spauldite	Spaulding Fibre Co.
Synthane	Synthane Corp.
Micarta	Micarta Division Westinghouse Electric & Mfg. Co.

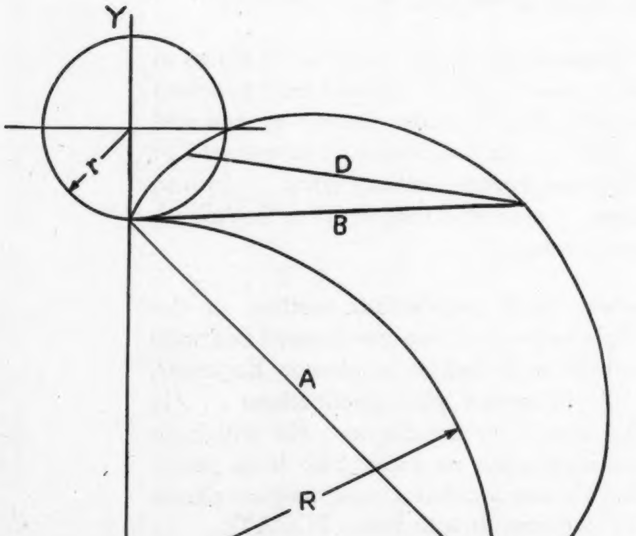
PROFESSIONAL VIEWPOINTS

MACHINE DESIGN welcomes comments from readers on subjects of interest to designers. Payment will be made for letters and comments published

"... limits for approximate formula"

To the Editor:

In the February issue of MACHINE DESIGN the Engineering Data Sheet entitled "Formula Aids Calculation of Curve Length" presents a formula for computing the length A of circular arcs, when the chord length C and the angle 2α, expressed in degrees, between the tangents (or normals) at the two ends of the curve are given, C and A being expressed in the same units. It is formed from the first three terms of a rapidly converging series, and has a high accuracy, which is stated to be less than 3/100 per cent error for a circular arc up to 90 degrees subtended angle.



The author also makes a statement which we think requires further delimitation: "Any curve in which curvature changes are not too abrupt may be assumed equal in length to a circular arc having the same chord and the same angle between tangents (or normals) at the two ends of the curve." A number of examples with various curves have been made to test its accuracy.

For the parabola $y^2=4x$ the exact length of the parabolic arc, between the limits $y=0$ and $y=5$, is 8.3787 inches. Using the approximate equation, the length is found to be 8.496 inches which is 1.4 per cent too great.

Considering the two branches of the parabola lying between $y = -5$ and $y = +5$ the true length is $2\times 8.3787 = 16.7574$ inches. The approximate formula, however, gives a length of only 12.865 inches which is considerably off.

Consider the epicycloid, which is generated by a point on a circle radius r, rolling on the outer perimeter of another circle radius R. If R is four times r, the complete curve resolves itself into a quatrefoil with four cusps at the axes, one of which is shown in the figure. The exact arc length S of one of its foils, with chord A for $R=10$ inches and $r=2.5$ inches, by analytical geometry, is 25 inches.

The angle 2α subtended by this arc is 270 degrees, hence the approximate formula cannot be used. Further, it is evident to the eye that the foil is not even approximated by a circular arc having its center at the intersection of the normals to the ends of the curve.

If, however, we divide the foil arc so as to make two equal chords and use the upper one (chord B) the angle 2α is 135 degrees. The approximate formula ($\alpha=67\frac{1}{2}$ degrees, chord $=10.62$ inches) gives a length of 13.59 inches, which is 8.7 per cent greater than the exact value of 12.5 inches.

The example of the single branch of a parabola is practically close but the double branch, involving no greater curvature but only doubling in length, is much out. Here the maximum arc height is great relatively to the chord, and this suggests there should be a limit to this ratio for the approximate formula to apply.

In the examples of the epicycloid, which is a deceptive curve having short sharp curvatures not evident to the eye at the cusps, any part of this curve that includes the cusps will not be accurately rectified.

The suitable type of noncircular arc should be relatively flat, of slow curvature, have no point of inflection, should not be re-entrant, and should be such as to be cut in not more than two points by any straight line.

—CARL P. NACHOD

Nachod & United States Signal Co.

wherever a tube is used...

R. F. SHORT WAVE THERAPY

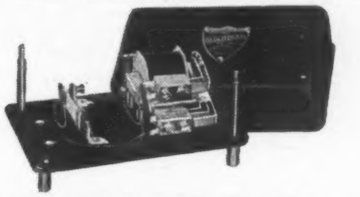
Radio Diathermy is used in therapeutic treatment of bruises, sprains, dislocations, arthritis, fractures, respiratory and sinus diseases. Oscillator type tubes generate the required high frequency.

THERE'S A JOB FOR

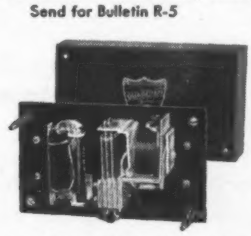
Relays BY GUARDIAN

The filaments of oscillator type tubes require a "warm up" of 20 to 30 seconds which is usually provided by a time delay relay such as Guardian's Type T-100. In this relay the time delay is adjustable between 10 and 60 seconds and is accomplished by means of a resistance wound bi-metal in series with a resistor. The contact capacity of the T-100 is 1500 watts on 110 volt, 60 cycle, non-inductive AC. The power consumption of coil and time delay during closing of the thermostatic blade is approximately 10 VA; after closing, 5.5 VA.

A similar relay giving almost the same performance but costing somewhat less is the Series T-110. This relay may be equipped with an extra set of open or closed contacts, if desired. In industrial control, both relays may be used in applications requiring the changing of circuits after a predetermined interval.



T-100 Laminated Time Delay Relay
Send for Bulletin R-5



T-110 Time Delay Relay (not laminated)
Send for Bulletin R-5

Consult Guardian whenever a tube is used—however—Relays by Guardian are NOT limited to tube applications but are used wherever automatic control is desired for making, breaking, or changing the characteristics of electrical circuits.

GUARDIAN G ELECTRIC

1601-G W. WALNUT STREET CHICAGO 12, ILLINOIS

A COMPLETE LINE OF RELAYS SERVING AMERICAN WAR INDUSTRY

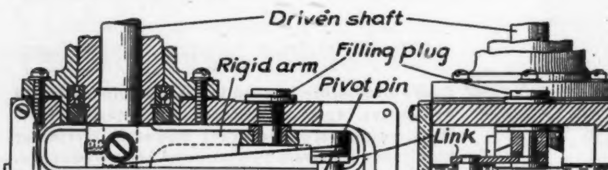
Noteworthy Patents

Coupling Isolates Vibrations

CAPABLE of effectively suppressing the transmission of velocity variation between driving and driven shafts is the mechanical coupling shown in the accompanying illustration. Covered by Patent 2,337,976, recently assigned to Western Electric Co., it has been developed for use in phonograph turntable driving mechanisms.

Referring to the illustration, the driving shaft is provided with a flange and an aligning projection extending into a corresponding aperture in the housing. The housing is secured to the driving shaft by means of machine screws extending through the flange into the housing. A gasket prevents leakage of damping fluid from the housing.

Driven shaft extends into the top of the housing in axial alignment with the driving shaft and is free to rotate on ball bearings relative to the housing. A flat reed spring having one end secured by machine screws to the housing directly above the center of the driving shaft extends radially from the shaft into a narrowed portion of



Reed spring immersed in fluid transmits torque, isolating vibrations between driving and driven shafts

the housing. Lower portion of the housing is completely filled with a suitable damping fluid. Extending radially from the driven shaft is a rigid arm secured by means of a set screw. Free end of the arm and the free end of the reed spring are coupled through a mechanical linkage which includes a bearing slot secured to the free end of the reed spring, a pivot pin and a link connecting the pivot pin and the rigid arm.

Filling plug is provided with a reduced extension which fits into a hole in the rigid arm. This construction provides a limiting stop to prevent injury to the flexible element of the vibration-absorbing coupling in case of excessive relative rotation, particularly during starting and stopping.

The coupling may be balanced with respect to the shaft by the use of suitable counterweights or, in power transmission systems involving greater power or higher speed, the length of the housing on opposite sides of the shaft may be made equal and an additional pair of coupling members provided. Inasmuch as the flat reed spring is completely surrounded by the damping fluid in the confined channel, movement of the spring relative to the housing in response to velocity variations is effectively damped by the dashpot action of the spring and the damping fluid in the confining channel. The amount of damping may be controlled by the choice of damping fluid and by a suitable choice of the clearance between the edges of the reed spring and the sidewalls of the chamber portion of the housing.

Synchronizing Speeds of Multiple Units

WHERE the speeds of two or more rotating units such as the engines of a multiengine airplane must be synchronized, indicating tachometers fail to show sufficiently small differences. Although they may indicate substantially the same speed for each unit there may actually be as much as 20 or 25 revolutions per minute difference. This disadvantage is overcome through the use of a synchroscope covered by patent 2,339,612, recently assigned to Bendix Aviation Corp. Provision is made for indicating the speeds of two engines on separate tachometers which are interconnected through one or more electrical impedances. When the speed of one engine varies with respect to the other, the tachometer indicators oscillate once per cycle difference.

Each engine drives a generator consisting of a permanent-magnet rotor and a stator with a three-phase winding. The three-phase windings are connected by suitable leads with the three-phase windings of synchronous indicator motors. Rotor of each indicator motor drives a permanent magnet which revolves inside a cup of nonmagnetic material, exerting a torque upon it by virtue of eddy currents generated in the material. The torque is opposed by a spring which allows the cup to turn in proportion to the torque upon it, and operating a pointer to give indications which are proportional to the engine speed. The pointers which indicate the two engine speeds are assembled in one instrument housing and move over the same graduated scale.

In order to furnish an indication of speed differences, an electrical impedance member is connected across corresponding points of the stator windings of the two indicating motors. As long as the two speeds are identical, the two indicating pointers coincide, the indicator motors running at constant uniform speed. Whenever one engine begins to speed up, however, the system no longer maintains constant voltage and phase relationships and the indicator motors speed up and slow down once per cycle difference, causing the two pointers to oscillate relative to each other. Thus, to synchronize the engines the pilot need only adjust the speed control until the pointers coincide and no longer oscillate.


INCO

Design Abstracts

Synthetic Rubber for Belting and Hose

FOR conveyor and elevator belts, Buna S (GR-S) belt covers may be expected to give good service in the carrying of such materials as sand and gravel, fine ores, trap rock up to 2-inch size, salt, sugar, etc., with some cutting and chipping when used for large size stone, ore, etc. Lack of resiliency of GR-S can be compensated somewhat by using thicker covers than now permitted.

Neoprene (GR-M) belts can be recommended for the heaviest and most bruising types of service and where heat resistance is required. Care should be exercised with its use at low temperatures. More service history is needed to develop the economic value of the higher cost of GR-M belts as compared with the less expensive belts made from GR-S.

For Best Flex Life

Best flex life for flat transmission belts is found with the use of GR-M, which should be used where oil is present, under elevated temperatures, for most severe flex conditions, and where long life is expected. GR-S belts can be used where flex conditions are not quite so severe. Their chief limitation is one of heat.

V-Belts will use GR-M for special oil and heat-resisting purposes. It will probably replace rubber for belts operating near the top range of heat and will also replace belts which have maximum flexing. If belts operate at normal temperatures, then GR-S belts may be expected to give just as satisfactory life as have the "war" belts and will be much better than the all-reclaim belt.

Selection of Hose Material

With rubber and synthetic rubber hose no difficulty is expected with water service if the proper selections of GR-S and reclaimed rubber are used. Air hose should be made of GR-M to secure longest life. Where compressed air is relatively free from oil and temperatures are not excessive, GR-S will make a highly satisfactory hose. In steam hose heat materially reduces the physical properties of GR-S, yet if proper strength members are employed satisfactory hose can be made. Unfortunately GR-M has more tendency to absorb hot water and it seems questionable whether it will justify its higher cost.

For hoses to carry abrasive materials, GR-M possesses higher abrasive resistance, yet it is thought that GR-S will have sufficient resistance to prove its economical worth. Such hoses will have a short life if they are bent at too sharp a radius. More experience is needed.

How far and how fast we progress will depend upon the effectiveness of the united efforts of producers, consumers, and the users of these synthetic rubber products. Such industrial teamwork has and always will make our country a great industrial nation.—*From a paper by W. L. White, Manhattan Rubber Mfg. Div. of Raybestos-Manhattan Inc., presented at the spring meeting of the A.S.T.M. in Cincinnati.*

More Power from Diesels

OF THE recent advances in diesel engineering the most significant pertain to the 2-stroke-cycle engine. Since pure air is charged into the cylinder, scavenging can be done with air without wasting fuel, making the 2-stroke cycle practicable for the diesel.

Most efficient type of scavenging for 2-stroke-cycle engines is the uniflow or straight-through scavenging. Roughly 20 per cent more air can be trapped in that manner than by cross or loop scavenging. There are three ways known to produce uniflow scavenging in a cylinder: Poppet valves in the head, opposed-piston design, and sleeve or slide valves.

Sleeve Valve Developments

Advantage of the 2-stroke-cycle sleeve-valve engine lies in the absence of poppet valves, which permits the use of simple symmetrical cylinder heads. High power output is the result. Its disadvantage is the difficulty of cooling and lubrication because of the sleeve. Sleeve-valve diesels now are being developed for marine and aircraft propulsion. A 20-cylinder sleeve-valve aircraft engine in an advanced stage of development is to give 2000 horsepower on one shaft and to weigh 1.8 pound per horsepower.

If air charge is forced into the cylinder with superatmospheric pressure, the amount of charge can exceed displacement volume. This supercharging is becoming popular with 4-stroke-cycle diesel engines, the main objective being to increase power output at sea level.

At present, engine cooling puts a practical limit to the supercharging of the diesel engine because more heat has to be taken care of to prevent overheating. Sticking of piston rings, burning of pistons, cylinder heads, and exhaust valves frequently give trouble in highly supercharged engines. Complete solution of these problems is a time-taking process, but progress is being made. Porous-chromium-plated cylinders and piston rings, oil-cooled pistons, sodium-cooled valves, directed high-speed water cooling, and compounded lubricating oils are a few recent developments in this direction.—*From a paper by P. H. Schweitzer, Pennsylvania State College, presented at an S.A.E. section meeting in Philadelphia.*

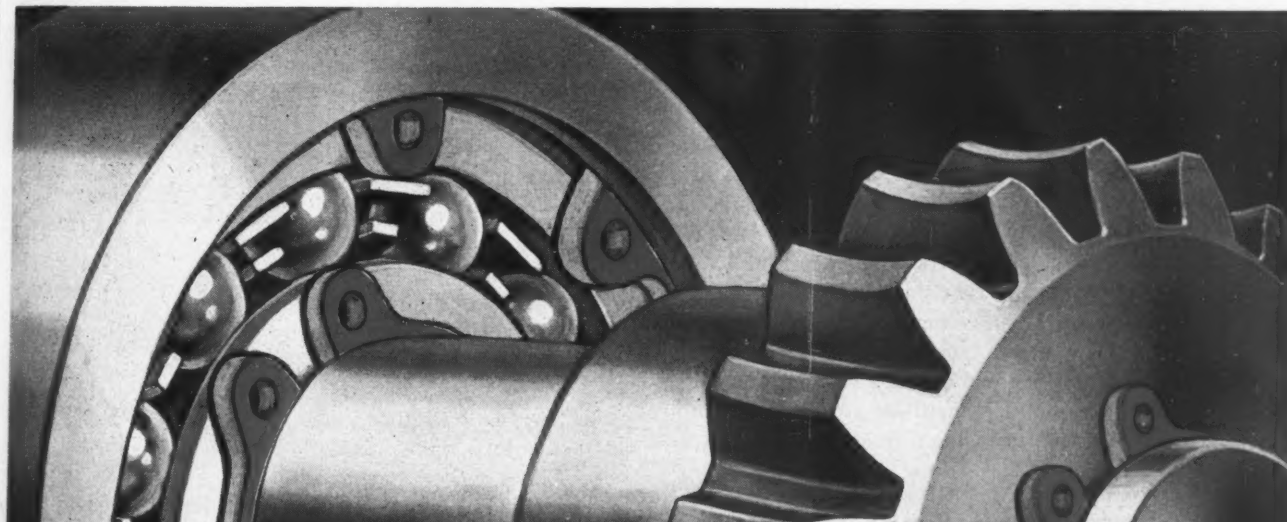
Waldes Truarc presents a significant advance in retaining rings.

It spreads or contracts without distortion; always retaining its perfectly fitting circular contour.

WALDES TRUARC RETAINING RING

For thrust-load fixing, and shaft and housing applications, Waldes Truarc provides distinct advantages over nuts and bolts or wedges and washers... it reduces dimension and weight... saves material... cuts manufacturing time... simplifies assembly and dis-assembly.

On request, we will gladly furnish samples and full data for your tests.



U. S. Patent Re 18144

WALDES KOH-I-NOOR, INC ★ LONG ISLAND CITY, N. Y.

Sole Manufacturers in U.S.A.

Canadian Representatives: Prenco Progressive and Engineering Corp., Ltd., 72-74 Stafford St., Toronto

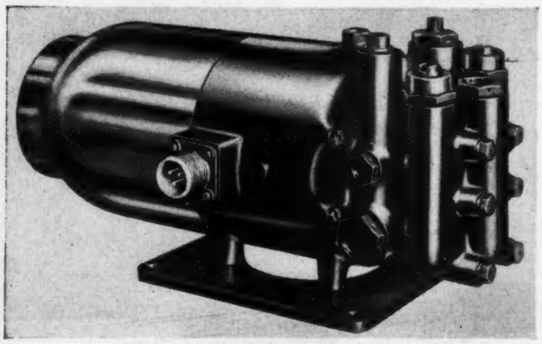
New PARTS AND MATERIALS

Post-Forming Laminated Plastic

NEWLY DEVELOPED post-forming material known as Grade 906 is being supplied by the Panelyte division of St. Regis Paper Co., 230 Park avenue, New York 17, as a fully cured, laminated thermosetting sheet. It can be stamped, bent and drawn in a process similar to that used in metal stamping. The molds used in this process are of Kirksite, cast phenolic, laminated phenolic, or wood. Working of the sheet is accomplished by heating it to temperatures higher than those originally used in its manufacture. It is not necessary to use hot molds, but merely to heat the material, mold it, and leave it for a short period in the mold for partial cooling. From this grade durable laminated phenolic parts having compound curvatures and fairly sharp bends can be made. Bends having inside radius of the thickness of the material are practical. High pressures are not required. Small air cylinders are suitable, and in some cases even hand presses will suffice.

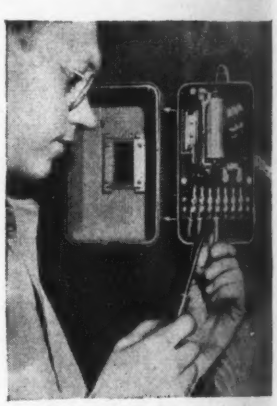
Hydroelectric Power Unit

WEIGHING ONLY 8 pounds, the new hydroelectric power package of Pesco Products Co., 11610 Euclid avenue, Cleveland 6, combines a reservoir, an electrically driven pump, a pressure relief valve and a pressure switch.



By the use of this system, the number of units in a plane's hydraulic control system is reduced to three. Long lines for the transmission of hydraulic power are eliminated because the power unit may be installed close to the hydraulic cylinder. The systems are being designed for operation at 3000 pounds per square inch. Tests of the new gear-type hydraulic pump for aircraft have shown volumetric efficiencies above 90 per cent and torque efficiencies above 70 per cent, with the added advantage of satisfactory operation at temperatures ranging from −85 to 160 degrees Fahr. Hydraulic loading of the pump's floating bushings is said to be responsible for the improved performance.

Electronic Relay Amplifies Current



TO INCREASE the application range of many control devices, General Electric Co., Industrial Control division, Schenectady, N. Y., has introduced its electronic relay which amplifies limited current transmitted by delicate control contacts or high resistance circuits. Operated by any material having a resistance of from 0 to 500,000 ohms, or greater if necessary, the new relay is suitable for controlling liquid levels in tanks and boilers, sorting metallic parts by size, detecting broken threads in textile machines, and as a limit switch requiring extremely light pressure to operate. Small and light in weight, the relay consists of a standard type electronic tube, a supply transformer, and an electromagnetic relay—all mounted in a totally enclosed, weather-resistant enclosure. In operation the electromagnetic relay is kept energized as long as the controls connected to the input grid circuit of the electronic tube remain open. As the contacts close, the relay is de-energized. A built-in time delay feature prevents chattering when the contacts in the input circuit are closed momentarily. A contact arrangement on the electromagnetic relay permits the device to be used either to make or break a load circuit when the actuating contacts connected to the input circuit on the electronic relay are closed.

Sensitive Multipole Relays

IMPROVEMENT IN the design of its sensitive type 27 multipole relays has been made by G-M Laboratories Inc., 4300 North Knox avenue, Chicago 41. The top contact structure has been redesigned on the 3, 4 and 5-pole re-

Photo Galland-Henning Co.

This is a heavy duty, triple compression hydraulic baler, which makes little bundles out of big pieces of metal scrap.

The hydraulic medium operating the three rams is sealed by VIM Leather Packings. These packings are great favorites because huge underground installations such as this need less attention when packed with long-life VIM Leather.

Engineers like the design service rendered by our Leather technical men. If you are designing a hydraulic mechanism, Houghton stands ready to help in planning the packing installation. Call in the Houghton Man, or write—

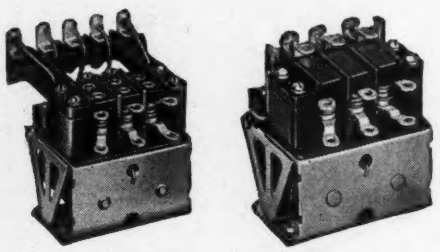
E. F. HOUGHTON & CO.

PHILADELPHIA

CHICAGO SAN FRANCISCO DETROIT

HOUGHTON'S *Engineered* VIM *Leather Packings*

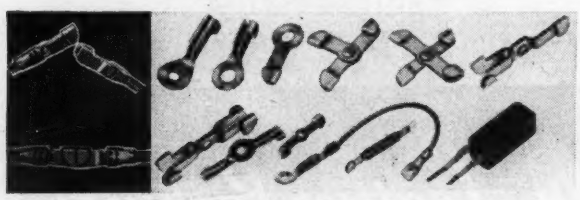
lays. Formerly all coil and blade contact terminals were located on an overhanging bakelite bracket. The relay with the new top contact structure is shown at the right in the accompanying illustration. It is recommended especially for applications where space is limited, where heavy contact loads are to be handled, where vibration or shock is encountered, and particularly where the power input to the coil is limited. The two-coil design is an important factor. Magnetizing force losses at the armature hinge are completely eliminated, and a greater number of wire turns for a given resistance are permitted, resulting in more ampere turns and correspondingly a greater operating force for a given power output. Rigid framework provides immunity to effects of high acceleration, severe



vibration or shock, and the semibalanced armature provides vibration resistance within limited space. The box-shaped support for the stationary contacts affords protection against mechanical damage and dirt. Contacts operate with a wiping action, insuring positive electrical contact. Depending upon available power and on coil and circuit characteristics, contact capacity ranges up to 10 amperes continuous at 30 volts direct-current on inductive (motor) circuits based on operation at 53,000 feet altitude. Ambient temperatures range from −40 to 90 degrees Cent. Weight is 4½ to 6½ ounces, depending on the number of poles. Coils are both varnish and vacuum-wax impregnated, and all metal parts are either noncorroding or are heavily plated. The relays will withstand severe humidity tests as well as the Army-Navy 200-hour salt-spray test (Spec. AN-QQ-91).

Solderless System for Connections

DEVELOPED BY Aircraft-Marine Products Inc., 15910 North Fourth street, Harrisburg, Pa., solderless connectors facilitate the assembly of single and multiple-wire systems. These solderless knife-disconnect splicing units incorporate



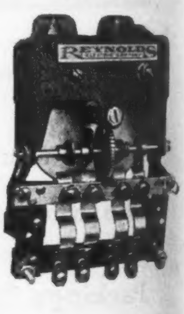
the company's basic design of splicing terminal in which identical ends are put into 4-point electrical connection by knife-wiping action. The connection is maintained until taken apart. This design has been adapted to "T-Link", "Y-Link", "H-Link" and "Cross-Link" applications, and to stud tabs, jumpers and small electrical assemblies such as switches, relays, etc. Other applications are being designed to specifications. The manufacturer's hand, foot and power installation tools are precision-engineered to make quick, perfect crimps of terminals to wires. Terminals are fully-annealed, hot-electrotinned copper. The Diamond Grip insulation support type terminal is available in wire sizes 22 to 10, and the Standard Type B in wire sizes 22 to 8.

Coated Aluminum-Bronze Electrode

FOR PRODUCING welding deposits of high strength and ductility combined with resistance to corrosion, the Wilson Welder & Metals Co., 60 East Forty-second street, New York 17, has announced the availability of a new coated aluminum-bronze electrode; the No. 200. It is a shielded arc electrode and can be used also as a filler rod in carbon arc welding. The rod has a universal application in the welding of most bronzes, malleable and cast iron or steel. Other specific applications for which it is especially suited are welding manganese bronze conforming to Federal Specifications QQ-B-726b, or Navy Specifications 49-B-3e for marine propellers and other parts where great strength, ductility and corrosion resistance are required. The electrode can be used also for welding dissimilar metals, such as cast iron to brass, steel to malleable iron, or joining of any two metals which are weldable with aluminum-bronze. Sizes in which it is available are from ⅛ to 3/16-inch in 14-inch lengths, and ¼-inch in 18-inch lengths. Sizes from 5/16 to ½-inch in 18-inch lengths can be obtained on special order.

Motor-Driven Control Improved

ANNOUNCED BY Reynolds Electric Co., 2650 West Congress street, Chicago, the motor-driven control consists of a series of four motor-driven revolving cams, made of insulating material. Each cam has an accompanying contact finger with silver tip, operating on the make and break principle. Shape of the cam and the speed at which it revolves determines the period each electric circuit remains open or closed. It is precise and positive in action, and quiet in operation. By varying the size of contacts and the speed of operation, timing and action can be changed. The control is designed for 110-volt 60-cycle current only. Size is 7 x 8 x 3½ inches, and weight is 10 pounds.



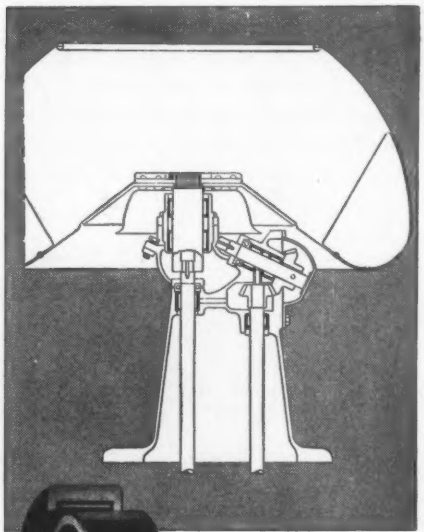
Direct-Current Series Motor

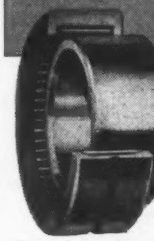
PRIMARILY designed to operate blowers for cooling purposes in aircraft equipment, a direct-current series motor is now being produced by Alliance Mfg. Co., Alli-

IN THE NEWS

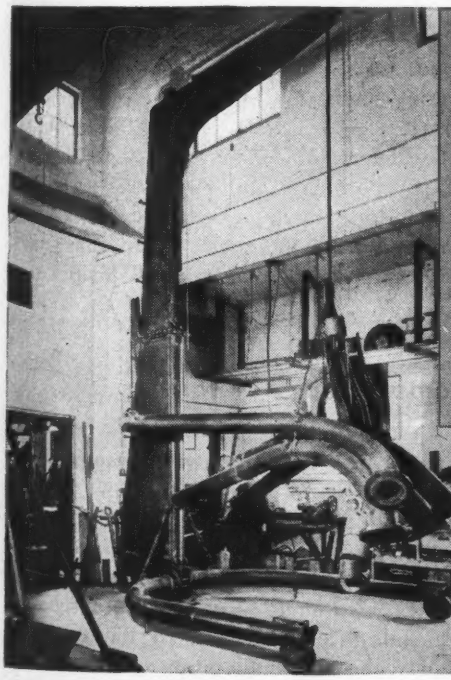
WITH TORRINGTON BEARINGS

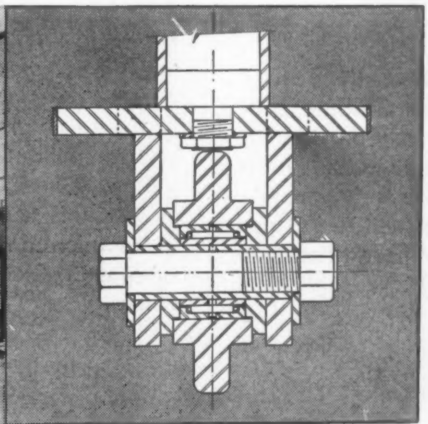
A 95-FOOT "STRETCH" is available through this Hi-Reach Platform Telescoper, product of the Economy Engineering Company, used for plane and hangar maintenance by our Army Air Forces. Torrington Type DC Needle Bearings were supplied for the twenty-two hoist mechanism sprocket shafts. These bearings were selected because of their compact design features coupled with extremely high capacity, permitting light but strong construction in the telescoping mechanism.



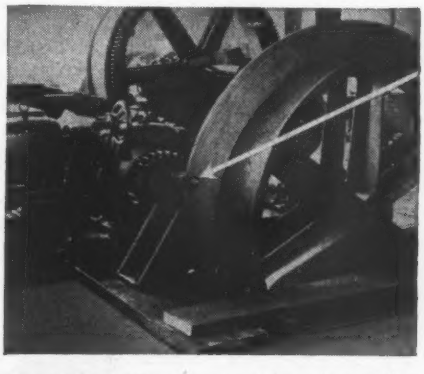


THE DRY CLEANING BUSINESS is at an all-time peak and equipment is being subjected to severe performance tests. Cross-section shows the application of Torrington NCS Needle Bearings in the pedestal assembly of a dry cleaning unit manufactured by Columbia Appliance Corporation. Now operating almost continuously day after day, these compact anti-friction bearings are demonstrating the advantages of their high capacity and long service life under heavy load conditions.





THIS PORTABLE HYDRAULIC HOIST, manufactured by Federal Aircraft Works primarily for aircraft engines, handles other heavy parts with equal facility. Cross-section shows installation of Torrington Type NCS Needle Bearing in the hydraulic ram sprocket, where it is subject to extremely heavy loads. Its low coefficient of friction is an important factor in contributing to smooth, anti-friction operation.



CAM FOLLOWERS have proven to be an interesting application of Torrington Type RC Needle Bearings in the wire manufacturing machinery of New England Butt Company. They are used to impart a "wobble" motion to the loose fitting ring on the drum of the capstan, the ring guiding the wire so that it "lays" correctly on the drum which revolves at a maximum speed of 125 feet per minute. The high capacity and elimination of stress concentrations of these heavy duty Type RC Torrington Needle Bearings make them ideal for this purpose.

TORRINGTON-BANTAM ENGINEERS, with long experience in the design and manufacture of anti-friction bearings of every major type—tapered roller, straight roller, needle and ball—are in an unusual position to give expert assistance in the design and selection of the correct bearings for any given application. For assistance with today's or tomorrow's bearing problems, TURN TO TORRINGTON.

ARMY E NAVY

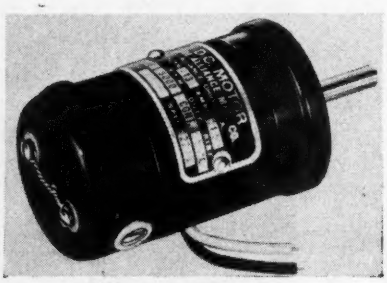
TORRINGTON BEARINGS

STRAIGHT ROLLER · TAPERED ROLLER · NEEDLE · BALL

THE TORRINGTON COMPANY · BANTAM BEARINGS DIVISION

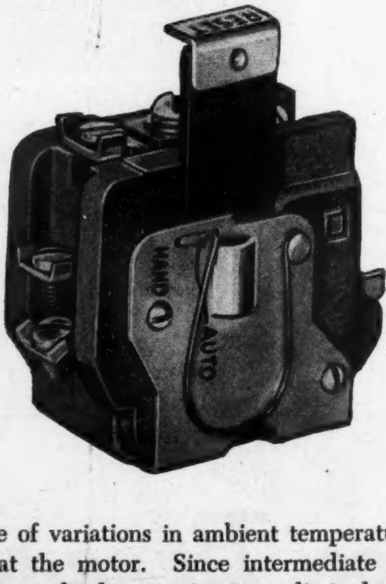
SOUTH BEND 21, INDIANA

ance, O. The unit operates on 28 volts direct current source at .75 amperes delivering a full 1/80 horsepower at 8000 revolutions per minute. Of the latest approved aircraft design, it is light in weight and has high efficiency consistent with sturdy, totally enclosed, ball bearing construction. Overall measurements, less the ¼-inch diameter shaft extension, are 3 inches in length and 1⅞ inches in diameter. It weighs 17 ounces. Low temperature rise permits operation under high ambient temperatures. The basic design of the motor can readily be modified to meet other volume applications with either shunt or series winding for desired voltage, current drain and horsepower output to 1/50 consistent with speed and duty cycle.



Bimetallic Overload Relay

RECENTLY ANNOUNCED by the Industrial Controller division, Square D Co., 4041 North Richards street, Milwaukee 12, the new bimetallic overload relay provides an easy and positive method of changing from automatic to hand reset. An unusual feature of the relay is a simple means of adjusting the tripping point from 85 to 115 per cent of nominal rating. Changes can be made in settings to take care of variations in ambient temperature or load conditions at the motor. Since intermediate points can be obtained, overload protection is not limited to the usual selection of heater sizes. Known as Type AR relays they are designed for separate or front mounting on Size O and I starters, and are needed whenever starters are mounted in remote or inaccessible locations. The relays are suited particularly for use in built-in machine tool controls because they eliminate the need for external reset mechanisms.



New Basic Resin Developed

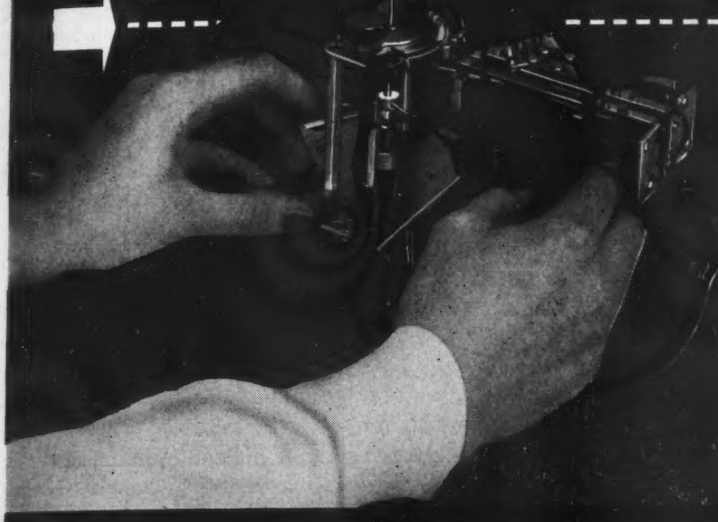
KNOWN AS DURALON, a new basic resin developed by The United States Stoneware Co., Akron, O., is characterized by its virtually zero water absorption, its insolubility (after inactivation) in any solvent, its high electrical resistivity, its stability in storage, and its ease of workability. Made from waste agricultural products such as oat hulls and corn cobs, it belongs to the group of synthetic materials known as the furanes. In its pure form, the resin is a heavy, viscous liquid, dark maroon in color, and on incorporation of catalysts and application of mild heat, it reverts to an extremely hard, dense, black substance. Varying physical, chemical and electrical properties can be developed in the base resin by incorporation of the usual fillers and lubricants. In certain stages Duralon can be machined readily. While preliminary studies indicate that the material can be molded, its immediate importance is as an impregnant, as a laminating and bonding agent, or as a protective coating material. Solutions may be applied as coatings by any of the conventional processes, or may be used for impregnation of porous materials such as stone, cement, plywood, asbestos, glass fibers, or other fibrous materials, or as a bonding agent for abrasive compounds, powdered metals, etc., or for adhesive bonding of fibrous materials to each other. Prior to application of heat, the coatings are soft and flexible, but as heat is applied they remain thermoplastic up to a point at which they become increasingly thermosetting, depending upon type and extent of activation. Other resins, shortly to be made available, are completely nonthermosetting and have interesting plasticizing, wetting and tackifying properties over wide temperature ranges.

Compressed Air Purifier

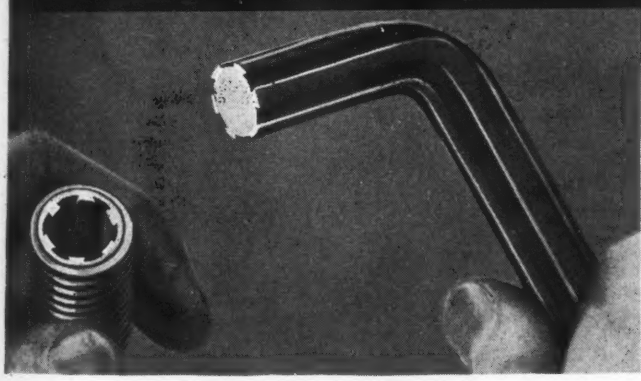
MAKING POSSIBLE purification of compressed air engineered to any volume or pressure, the new unit announced by the purifying division of Bird-White Co., 3119 West Lake street, Chicago, eliminates the condition which exists in compressed air systems—that of moisture, scale and oil being passed along to the point of discharge. Utilizing the principle of centrifugal force, the unit traps moisture, oil and scale, and only purified air is passed along through the compressed air system to the discharge point. The air entering the Pur-O-fier from the intake pipe rotates a high-speed, positive, noncushioning, perfectly balanced rotor which is sensitive to velocity. The rotor beats the atomized moisture and vaporized oil into larger particles which are driven outward and downward by a shroud. As they are cooled the entrainments are drained by gravity into a reservoir designed for manual operation. Units with automatic draining are provided also if desired. Openings at top of the shroud discharge purified air. The design of the baffles is based on the principle of aerodynamics and precludes the possibility

If It's Hard To Get At

it's Easy with..



THE SCREW THAT'S GEARED TO THE KEY



EASIER, FASTER ASSEMBLIES . . . greater holding power . . . convenient disassembly . . . are the reasons why Bristo Multiple-Spline Socket Set Screws are being used in tremendous quantities now that it is so important to specify the best. To accommodate greatly enlarged demand, manufacturing facilities have again been increased — this time by 25% — and further expansion is being planned.

THE TIGHTEST-SETTING SMALL SCREW ON THE MARKET

When the fastening point is awkwardly located or so small that it's hard to get at . . . or where vibration will be encountered . . . plan on using Bristo Screws.

The unique multiple spline design *gears* the screw to the key — for convenience in handling . . . and to utilize greater wrenching force without damage. The Bristo screw can be turned far beyond the point where an ordinary screw would burst or at least round out. Sizes as small as No. 4 wire can be set to withstand real vibration. Yet if adjustments need to be made, a flick of the key will loosen the screw.

Specified by leading aircraft and communications equipment manufacturers; ideal for electrical appliances, cameras, motor assemblies, instruments, etc. See other applications listed in THOMAS' REGISTER.

WHY "BRISTO" MEANS "TIGHTER"

MULTIPLE SPLINE SOCKET BRISTO SET & CAP SCREWS

Bristo: No expanding pressure; the key pulls the screw around.

ARMY E NAVY

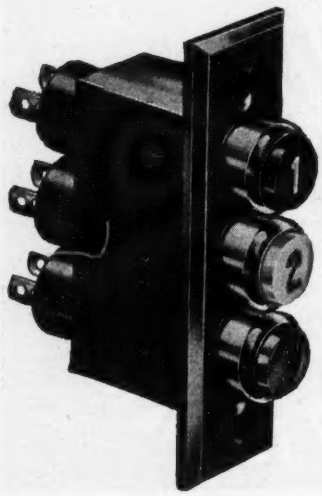
The BRISTOL *Company*
MILL SUPPLY DIVISION

BRISTO MULTIPLE-SPLINE SOCKET SET SCREWS

GEARED TO THE KEY — FOR FASTER, EASIER, TIGHTER SETTING

of capillary action resulting from high velocity. Two models are available: Model A-2 which has a 2-inch turbo-rotor and can accommodate volumes from 10 to 35 cubic feet; and Model A-4 which has a 4-inch turbo-rotor, accommodating volumes from 35 to 100 cubic feet. For volumes above this range, multiple units are recommended.

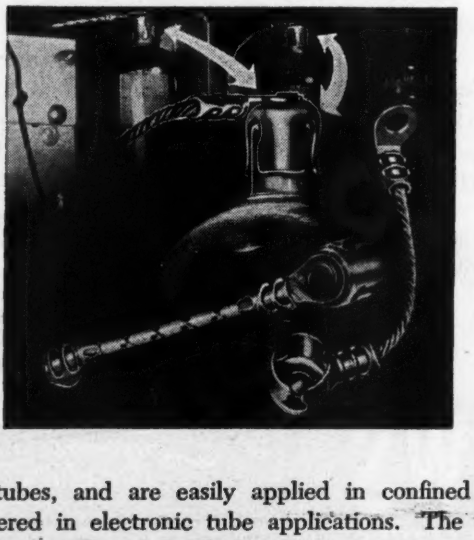
Pilot Light Assemblies



DESIGNED TO AID in the control of multiple coordinated circuits, the new "Trio-Light" pilot light assembly of Dial Light Co. of America Inc., 900 Broadway, New York 3, is obtainable in any size bank, in multiples of three pilot lights to each "Trio-Light". If an installation has twelve circuits, a bank of four "Trio-Lights" will be required. The light features color-coded flat lenses with etched numbers, letters or words. Half-round lenses may be used. Choice of colors includes red, green, amber, blue, yellow, opal, white and clear. Silver-plated terminals insure perfect contact under severe stress. Lamp sockets accommodate bayonet base lamps which are easily removable from front of panel.

Solderless Tube-Cap Terminals

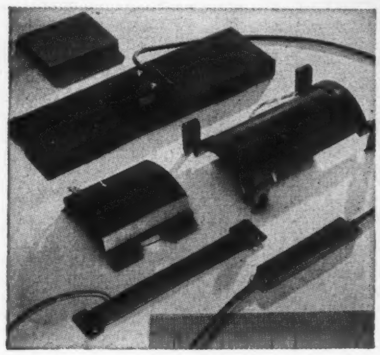
MANUFACTURED by Aircraft-Marine Products Inc., 15910 North Fourth street, Harrisburg, Pa., these recently announced solderless tube-cap terminals are designed for adaptation to heavy load, high-temperature operation on



power tubes, and are easily applied in confined areas encountered in electronic tube applications. The terminals are not affected by high tube temperatures. Cap and leads are made in various metals for operation in any range of temperature. Corrosion resistance is obtained by electrotinning the caps and leads. The Diamond grip tube-cap units are for insulated wire, while the Standard Type "B" units may be used on either insulated or non-insulated wire. Each type of tube-cap terminal is furnished individually or as an integral part of a complete lead built to customers' specifications. If it is desired to make up lead assemblies, hand, foot or power tools can be supplied.

Electric Contact Heating Units

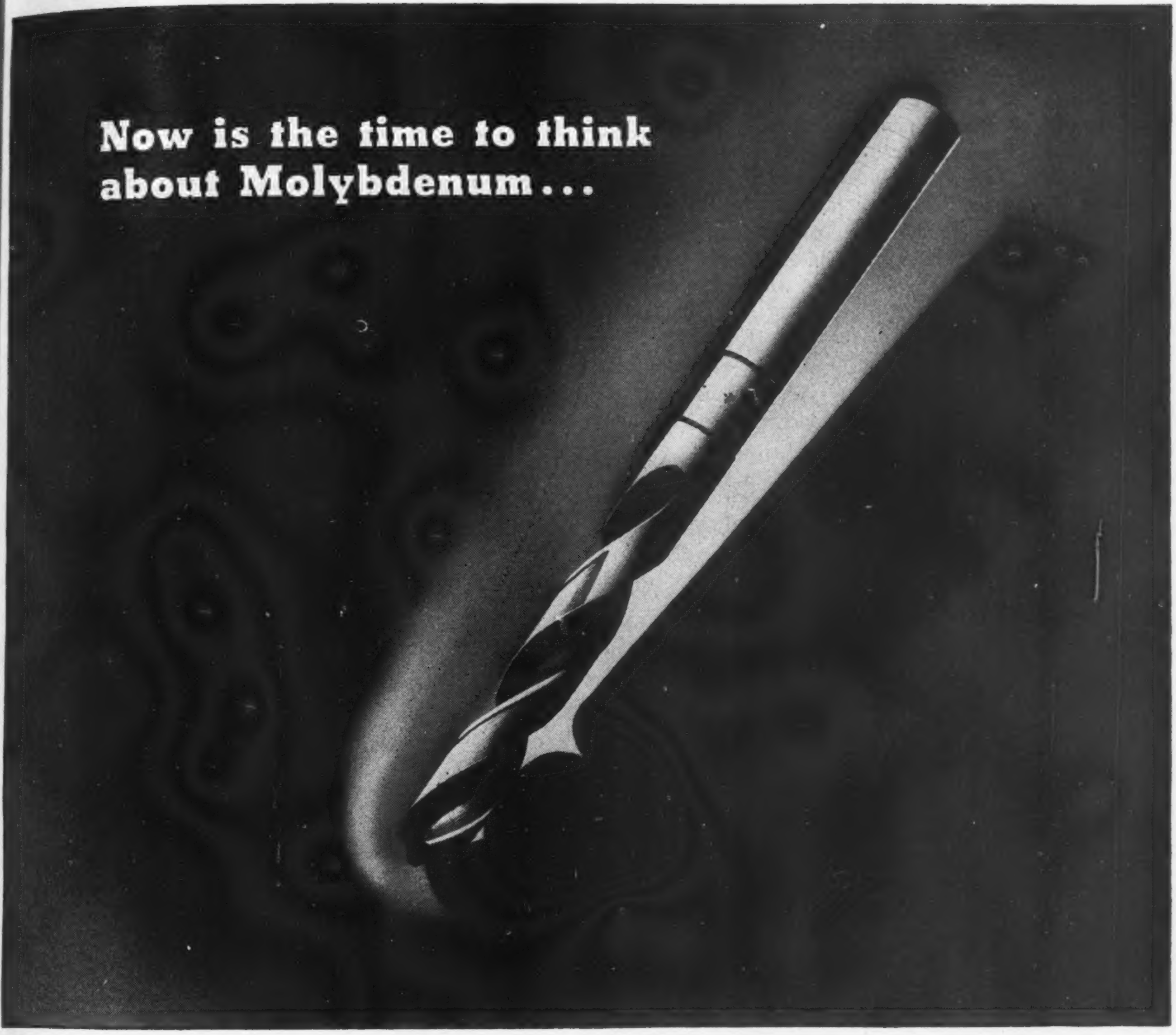
NEW TYPE OF heating units announced by H. & A. Mfg. Co. Inc., 86-100 Leroy avenue, Buffalo 14, N. Y., are serving a wide range of uses, principal among them being the heating of the bolt or firing mechanism on machine guns, the hydraulic actuating mechanisms on airplanes in the stratosphere, and storage batteries in army tanks in below-zero theaters of war. It is expected that they will be adapted to a multitude of peacetime uses as they can be made in nearly any size, contour and capacity, and have the advantages of light weight, low wattage, and of being safe in the presence of explosive vapors.



The units can operate without deterioration of the heating element, withstand vibration and maintain temperatures within close limits. Despite low-current consumption which ranges from 35 to 400 watts in the various sizes and shapes of units thus far developed, thermal losses are well controlled and heat transfer accomplished so that a unit weighing a few ounces will raise the temperature of 30-odd pounds of steel 90 degrees above sub-zero external temperatures. The face of the heating plate is held in compressive, resilient contact against surface through which heat is to be transferred. The units are "sprung" onto the object, requiring no nuts, bolts or other attachments. While they can be removed, their "grip" withstands severe vibration.

Electrode for Welding Aluminum

TO BE USED in welding aluminum sheet and castings, a new rod known as EutecTrode 2100 has been announced by Eutectic Welding Alloys Co., 40 Worth street, New York. This opens a new field for arc welding—the salvage and reclamation of aluminum castings—since it is



With both molybdenum and tungsten again available for use in high speed steel, consideration of their comparative performance is timely.

Before the war, a careful recording of comparative tests converted many users and tool makers to molybdenum high speed steel. During the tungsten shortage, when use of a high percentage of molybdenum types became mandatory, most users could not watch the performance of their tools carefully enough to draw conclusions on their respective merits.

Reports from large tool producers and users confirm that molybdenum high speed steels, when properly heat treated, perform at least as well under different kinds of shop conditions as the tungsten types which they replace.

Given equal performance on any particular type of work, an investigation of the saving in machining cost effected by molybdenum steels will prove well worth while.

CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.

ARMY E NAVY

MOLYBDIC OXIDE, BRIQUETTED OR CANNED • FERROMOLYBDENUM • "CALCIUM MOLYBDATE"

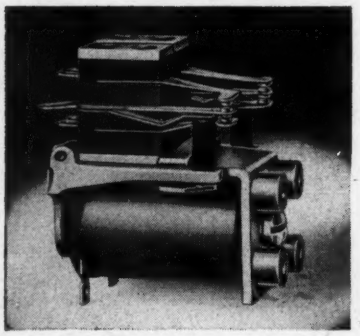
MOLY

Climax Molybdenum Company

500 Fifth Avenue • New York City

possible with the new electrode to add metal without completely preheating the casting and particularly without danger of overheating the metal adjacent to the weld. The operation is very rapid. In addition, the new electrode can be used in the joining of aluminum sheet. The high rate of fusion of this rod produces a smooth, strong, homogeneous fillet with speed, avoiding distortion and stresses. Leakproof joints are obtained which are machinable and show high tensile strength comparable to the parent metal. The rod is shielded with a special coating, permitting its application without preheating. It insures an even, rapid flow of metal, and slag can be removed by wire brushing the weld. The No. 2100 rod is a high-aluminum and low-silicon composition which alloys itself to practically every type of aluminum. It is available in 1/8, 5/32 and 3/16-inch sizes, with a long blue tip.

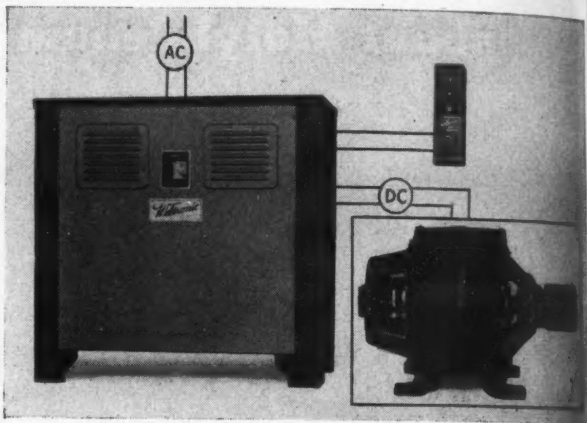
Small Telephone Type Relay



LATEST ADDITION to the line of telephone type relays produced by Allied Control Co. Inc., 2 East End avenue, New York 21, is a new small type developed for maximum magnetic efficiency with resultant sensitive operation at minimum power input. Specifically designed for high-frequency use, incorporating Mycalex insulation, the relay can also be supplied with Bakelite insulation for standard switching service. Coil is cellulose-acetate-sealed for resistance to humidity, meeting all standard salt-spray specifications. It will withstand shock and vibration to 10g. While the contacts normally are of palladium for maximum sensitivity, fine silver or special alloy contacts can be obtained on request. Double pile-ups of contacts can also be supplied. Weight and dimensions, less contact pile-ups, are 1½ ounces and 1 7/16 x 15/16 x 1 1/16 inches. Special tapped studs brazed to the frame permit easy mounting and prevent short circuiting of the coil.

Electronic Drives for D-C Motors

ANNOUNCED BY Weltronic Co., 20735 Grand River, Detroit 19, is a line of adjustable speed, electronic motor drives providing direct-current motor performance from alternating-current power without requiring special motors. Electronic rectifier tubes are used to convert alternating to direct current, supplying separate power to the direct-current motor armature and field circuits. Each circuit is individually controlled through other electronic tubes to provide speed adjustment and current regulation. The method used to control armature current prevents excessive current ripples. Full field strength of motor and limited armature current is utilized in starting in order to obtain maximum torque without causing excessive power line surges and consequent interference. Complete stepless control is obtained by setting a dial, ad-

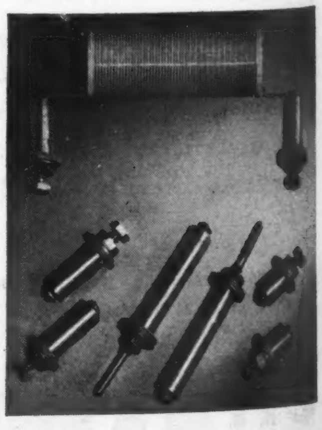


justable before or after motor is in operation. Capacities are from ½ to 3 horsepower single phase, and 5 to 10 horsepower three phase as standard, while other sizes or special designs for specific requirements may be supplied. Standard voltages are 220/440 at 60 cycles; 550 volt and 25 or 50-cycle units can also be supplied.

Bronze Die-Cast Links

METHOD OF casting conveyor chain links of Albro metal has been perfected by Bronze Die Casting Co., Franklin street at Ohio river, Pittsburgh 12. This bronze is resistant to sulphuric and other acids and alkalies. Conveyor chain links of any design may be cast with clean precision and sharpness, practically eliminating machining. The link shown in the chain illustrated is of new design and eliminates a connecting link which reduces wear and consequent stretch. However, any type of link required in conveyor chains can be furnished.

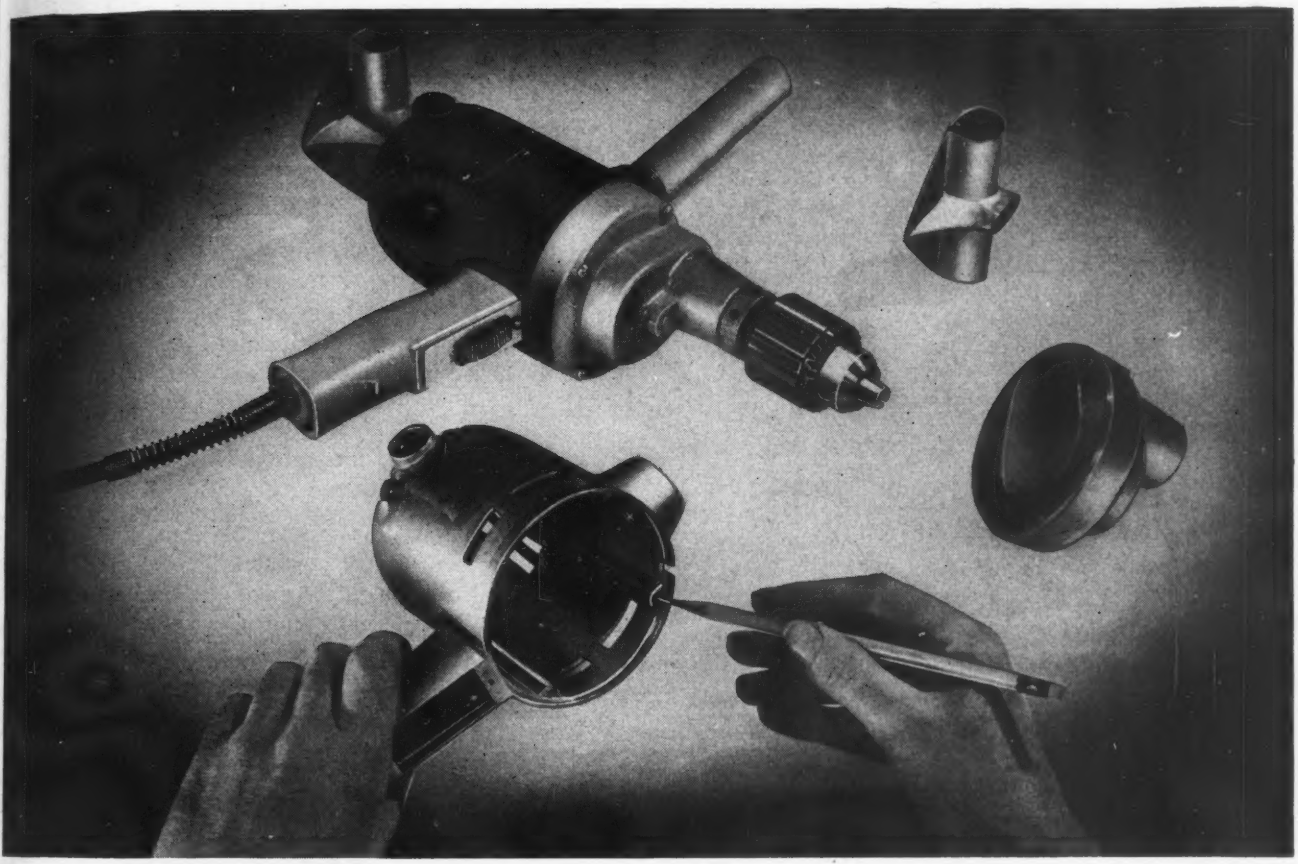
Infrared Heating Coil



ORIGINALLY designed for printing and textile machines, the infrared heating coil of The J. E. Doyle Co., 1224 West Sixth street, Cleveland, is finding new applications in other fields, especially on moving parts of machinery. The coil is constructed to withstand vibration and shock. Its cores are porcelain with grooves finished to take 60 turns of No. 23 nickel chromium wire. Patented windings at the ends keep wire

COMPLEXITY!

—59% LESS LABOR REQUIRED THRU THE USE OF 3 ZINC ALLOY DIE CASTINGS IN THIS DRILL



Zinc alloy die castings are solving many of today's labor shortage problems. For example, by redesigning this electric drill to utilize 3 zinc alloy die castings, a saving of 59% in machining labor was effected over the former material and method of manufacture. In dollars and cents, the overall cost of these 3 parts was reduced 46%—a major contribution in producing the lowest priced *quality* ½" electric drill now on the market.

Complexity of design presents the opportunity for these labor and cost savings. Consider, for instance, that the assembly elements are now integrally cast in the one-piece combined motor housing and handle (foreground). Imagine the number of operations which would be required to turn out the equivalent of this part by any other method of production!

Economy of production is only one of the reasons why die castings of zinc alloy are the most widely used under normal conditions. *Every die casting company is equipped to make zinc alloy die castings,* and will be glad to tell you about their many physical advantages—or write to The New Jersey Zinc Company, 160 Front Street, New York 7, New York.

ZINC

FOR DIE CASTING ALLOYS

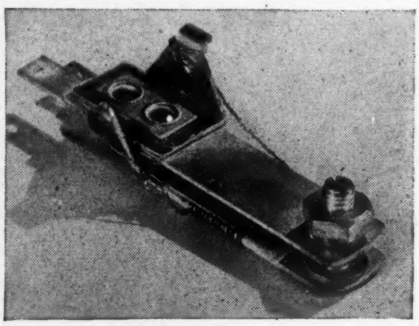
The Research was done, the Alloys were developed, and most Die Castings are specified with

HORSE HEAD SPECIAL (99.99+% Uniform Quality) ZINC

in position, preventing it from slipping off the core. Reinforced connecting ears reduce heat and furnish the resiliency needed to cushion vibration and shock. Lugs or connecting posts are furnished in a variety of lengths and terminal styles for various purposes. Any required degree of heat may be obtained by the use of multiple coils.

Compensated Time-Delay Switch

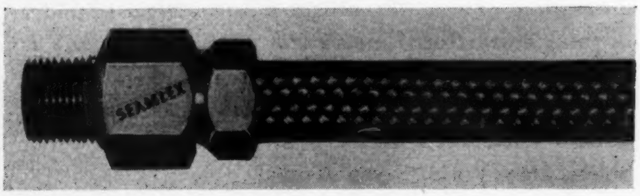
CONSTRUCTED FOR hard wear, the ambient compensated time-delay switch developed by George Ulanet Co., 88 East Kinney street, Newark 5, N. J., has a contact capacity of 1500 watts, 115/230 volts alternating current. Heater windings are wound for 6 to 230 volts.



The switch has heavy-duty electrolytic silver contacts and is available normally open or normally closed. Overall dimensions are 2¾ x ¾ x ⅝ inches; weight, ¾-ounce.

Fitting for Flexible Metal Hose

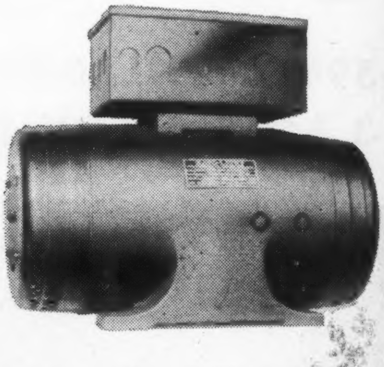
TO ITS LINE of detachable type fittings for flexible metal hose, The Seamlex Co. Inc., 27-27 Jackson avenue, Long Island City, N. Y., has added a ¾-inch inside



diameter fitting. The fitting consists of only three parts and provides triple safety against leakage. This is due to the metal-to-metal seat, the concentric guide which maintains the tube in correct central alignment, and the automatic stop which prevents stripping the thread and damaging the tube.

High-Frequency Motor-Generator

SHOWN IN THE accompanying illustration is a model from a new line of high-frequency motor-generators which has been announced by Kato Engineering Co., Mankato, Minn. Various combinations of alternating-current voltages and frequencies are available, such as either 400 or 800 cycles. Motor winding may be tapped to deliver



60 or 120 cycles at either 1800 or 3600 revolutions per minute. Voltages are from 60 volts on the tapped winding to 250 on the 800 cycle winding. Capacities of the unit are up to 1000 watts. Motor can be wound for direct-current voltages 110 to 220 volts direct-current input. This can also be furnished at three phase at slightly lower capacities.

Photo Copying Machine

FOR REPRODUCING one or more copies of any handwritten, typewritten, mimeograph, blueprint, photograph, rotogravure or printed originals or copies, the photo record machine of Photo Record Corp., 112 Liberty street, New York 6, is available in various models to handle different sizes and amounts of copy and reproduction

work. The No. 1518 B.P. pressure type printer is designed for volume work, to handle copies and originals 15 x 18 inches and smaller. Its plate glass copy area, firm pressure top and separate negative and positive light circuits speed operation and produce clear, sharp prints. A translucent glass diffuses proper light. No dark room is necessary. The model is 21½ inches deep and 15 inches high, weighing 45 pounds. Type No. 1518 A.P. printer has the same dimensions but weighs 47 pounds. It also handles the same sized copies and originals. In addition, it has a built-in synchronous motor automatic timer.

Undamaged after 7 years service

THIS PRESS for molding fiber sheets presented an unusually difficult problem in supplying steam to a multiplicity of moving parts.

Today, after seven years of heavy production without steam line failure, this manufacturer congratulates himself on having followed the advice of our Technical Department before setting up this press.

American Seamless Flexible Metal Tubing was selected for the steam lines. To meet the problem of friction or abrasion, the Seamless Tubing was encased in flexible, wear resistant American Interlocked Bronze Hose. Couplings are of brass, threaded for iron pipe connections.

If you have a problem involving the conveying of steam, air, water, oil or fuel, loading or discharging any material that will flow through a pipe, connecting moving parts or misaligned parts, isolating vibration or shielding electric wiring where the line must be flexible or resistant to abrasion, perhaps our Technical Department can be of assistance to you. Complete descriptive literature is available on request.

ANACONDA

American Metal Hose

AMERICAN METAL HOSE BRANCH OF THE AMERICAN BRASS COMPANY • General Offices: Waterbury 88, Conn.
Subsidiary of Anaconda Copper Mining Company • *In Canada:* ANACONDA AMERICAN BRASS LTD., *New Toronto, Ontario*

Men of Machines

AS THE NEW chief engineer of McCulloch Engineering Corp., Eugene W. Wasielewski will direct engineering work in the further development and application of the company's line of superchargers to diesel and gasoline engines for land and marine uses. Mr. Wasielewski was graduated from the University of Michigan with a Master's degree in engineering mechanics. After a few years of practical field work with turbines, blowers and internal combustion engines, he was attracted to the new and rapidly developing field of supercharging. When the war broke out, giving an impetus to supercharging for high-altitude flying, Mr. Wasielewski already had behind him four years of work with the National Advisory Committee for Aeronautics on design of superchargers and their adaptation to airplane engines. Since 1941, as supercharger project engineer for Ranger Aircraft Engines division and as executive engineer of the Stratos Corp., he has aided subsidiary companies of Fairchild Engine & Airplane Corp. to develop superchargers.

FORMERLY ASSISTANT chief engineer, Ben Van Zee has been appointed chief engineer of the Automotive division of Minneapolis Moline Power Implement Co. A native of Iowa, Mr. Van Zee received his early training in the farm machinery field in his father's implement business. His interest continued and he was graduated from the Agricultural Engineering school of Iowa State college. Desiring to specialize still further, he continued his studies at the college and in 1930 received his Master's Degree in agricultural engineering. During this time he served as a teacher for Mankato Teachers college and worked as a mechanical engineer for United Fruit Co. in Central America. This experience and work in Central America he obtained between his degrees at the Iowa State college. After receiving his degree he became associated with Minneapolis Moline in the engineering department. While there he has been in charge at various times of the experimental laboratory, experimental field work, and also has spent some time as a transmission design engineer. In 1937 he was promoted to the position of assistant chief engineer, and was placed in direct charge of design of all tractors and tractor engines.

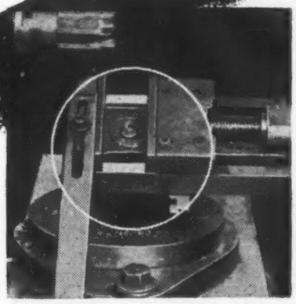
WITH HIS EXTENSIVE background in radio engineering, Roger M. Daugherty is well qualified to carry out his new duties as director of engineering of the Detrola Radio division of International Detrola Corp. Mr. Daugherty received his training at the University of Cincinnati, College of Engineering, and held several positions with various companies engaged in the radio field. Since 1926 he has been a licensed amateur radio operator, and since 1931, a licensed commercial operator. Prior to becoming connected with the Detrola Corp. in 1941, Mr. Daugherty was associated with Crosley Corp. He spent five years in its engineering department and two years in general development and design engineering. He then was made assistant to chief engineer of the Auto Radio Division and in a year became assistant chief engineer. After a year in this position he was placed on a special assignment for one year. His last position with the Crosley organization was in connection with government radio engineering and contracts. He joined the Detrola Corp. in 1941 which was merged into

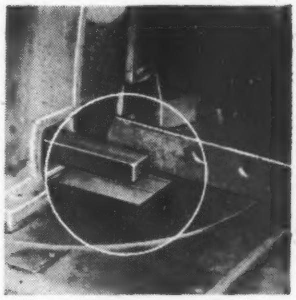
Does your Product have its *WEAK* points?

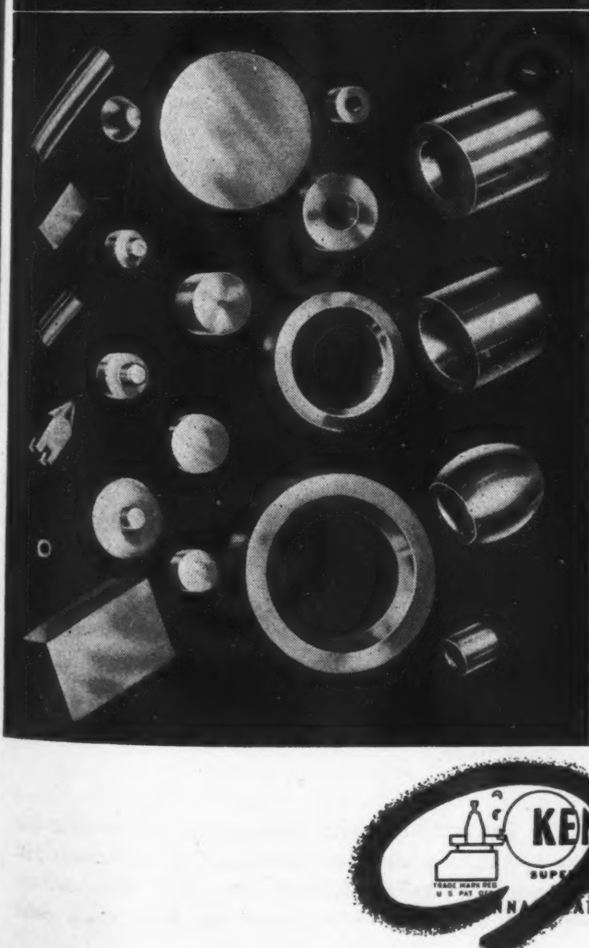
HARD **KENNAMETAL** PARTS

like these

ELIMINATE "WEAK" POINTS CAUSED BY WEAR







A heavy concentration of abrasive force on a small area usually results in a "weak" point that deteriorates fast, and has to be replaced more often than companion parts. That is, unless the weak point is reinforced with Kennametal—the unique cemented carbide composition that is up to 250 times as wear-resistant as steel! Kennametal is extremely hard (up to 80.6 on the Rockwell C scale). It is unaffected by ordinary causes of corrosion, and practically impermeable to gases and liquids. It is dimensionally stable—(creep is negligible). Its use minimizes galling, for it has an extremely low coefficient of friction with steel and other metals.

Kennametal can be employed to prolong precision life of almost any type of equipment. Two typical examples are illustrated above—Kennametal inserts in the vise of a milling machine, and the table of an abrasive cut-off saw. There are scores of other profitable applications. For instance, Kennametal-tipped pawls multiply the life of pawl and ratchet assemblies used in office machines, printing presses, a variety of tools such as boring braces, ratchet drills, jacks, and cranks, and many other devices.

Kennametal inserts can be easily incorporated into critical points of the product you manufacture. They are supplied . . . (1) accurately formed to desired shape, for brazing and finish grinding in your shop . . . (2) mounted on parts furnished by you, after which finishing is done either by you or by us . . . (3) embodied in complete parts produced by us. Write us about your wear-resistant problem We will show you how Kennametal can solve it

KENNAMETAL

SUPERHARD CEMENTED CARBIDES

TRADE MARK REG U S PAT OFF

KENNAMETAL *Inc.*, LATROBE, PA

the International Machine Tool Corp., under the name of International Detrola Corp. in 1943. In his new capacity as director of engineering, he is in charge of a large research and development program, with augmented technical staffs, involving both a broad program of radio-electronic war products and postwar radio-television and related projects.

♦

C. MORGAN RIFENBERGH, formerly design and development engineer for Westinghouse Electric & Mfg. Co., Lima, O., is now an independent research and development engineer. He will devote his efforts to aircraft instruments and allied equipment, and will be located in Port Huron, Mich.

♦

ACCORDING TO a recent announcement of Sullivan Machinery Co., James A. Drain Jr. has been appointed vice president in charge of product engineering, research and development for the company. He had been assistant to the president of the company for three years. Upon graduating from the Massachusetts Institute of Technology in 1926, he became associated with the Sperry Gyroscope Co., and later the Sperry Development Co., and still later Sperry Products Inc. He was connected with the Sperry organization for ten years, and much of this time was devoted to the development of the Sperry rail detector car. In 1937 Mr. Drain left Sperry and joined the Stefco Steel Co., where he became president. He remained in this position until accepting his new post as vice president in charge of engineering for the Sullivan Machinery Co.

♦

GEORGE P. SEMPLE has recently been made designer for the Hydraulic Press Mfg. Co., Mount Gilead, O.

♦

H. W. WHITMORE is the new chief engineer at Kold-Hold Mfg. Co., Lansing, Mich., succeeding R. E. SWART. Mr. Whitmore previously had been associated with Automatic Products Co., Milwaukee.

♦

ALEXANDER NORDEN, former executive vice president at L. A. Brach Mfg. Co., has become connected with product development activities at Aircraft-Marine Products Inc., Harrisburg, Pa.

♦

RICHARD K. BLACKBURN has been appointed chief of radio engineering and research at Crystal Research Laboratories, Hartford, Conn. Other appointments include those of NORMAN CHALFIN as radio and X-ray engineer, and RICHARD B. WOLCOTT as chief mechanical engineer of the company.

♦

BENJAMIN J. LAZAN, chief engineer, Sonntag Scientific Corp., Greenwich, Conn., has received the 1943 Alfred Nobel prize for work on plastics and metals under the effects of vibration.

♦

WILLIAM F. PLUME has been appointed chief engineer of Philadelphia Gear Works. ROBERT E. RICHARDS is assistant chief engineer.

♦

F. O. TRUMP has been made chief engineer at Ozalid Products Div., General Aniline & Film Corp., Johnson City, N. Y. G. P. MITCHELL is his assistant.

♦

CLARENCE C. HELMLE has been appointed plating equipment engineer-designer at Enthone Co., New Haven, Conn.

♦

A. J. VOJTKO replaces TOM HEATHER as design engineer at M. B. Austin Co., Northbrook, Ill.

♦

GASTON F. DUBOIS, vice president of Monsanto Chemical Co., is the recipient of the Perkin Medal awarded by the Society of the Chemical Industry.

♦

GLEN DAVID BAGLEY, head of the experimental engineering group at Union Carbide & Carbon Research Corp. Inc., New York, has been awarded the Jacob F. Schoellkopf Medal for 1944 by the Western New York section, American Chemical Society.

♦

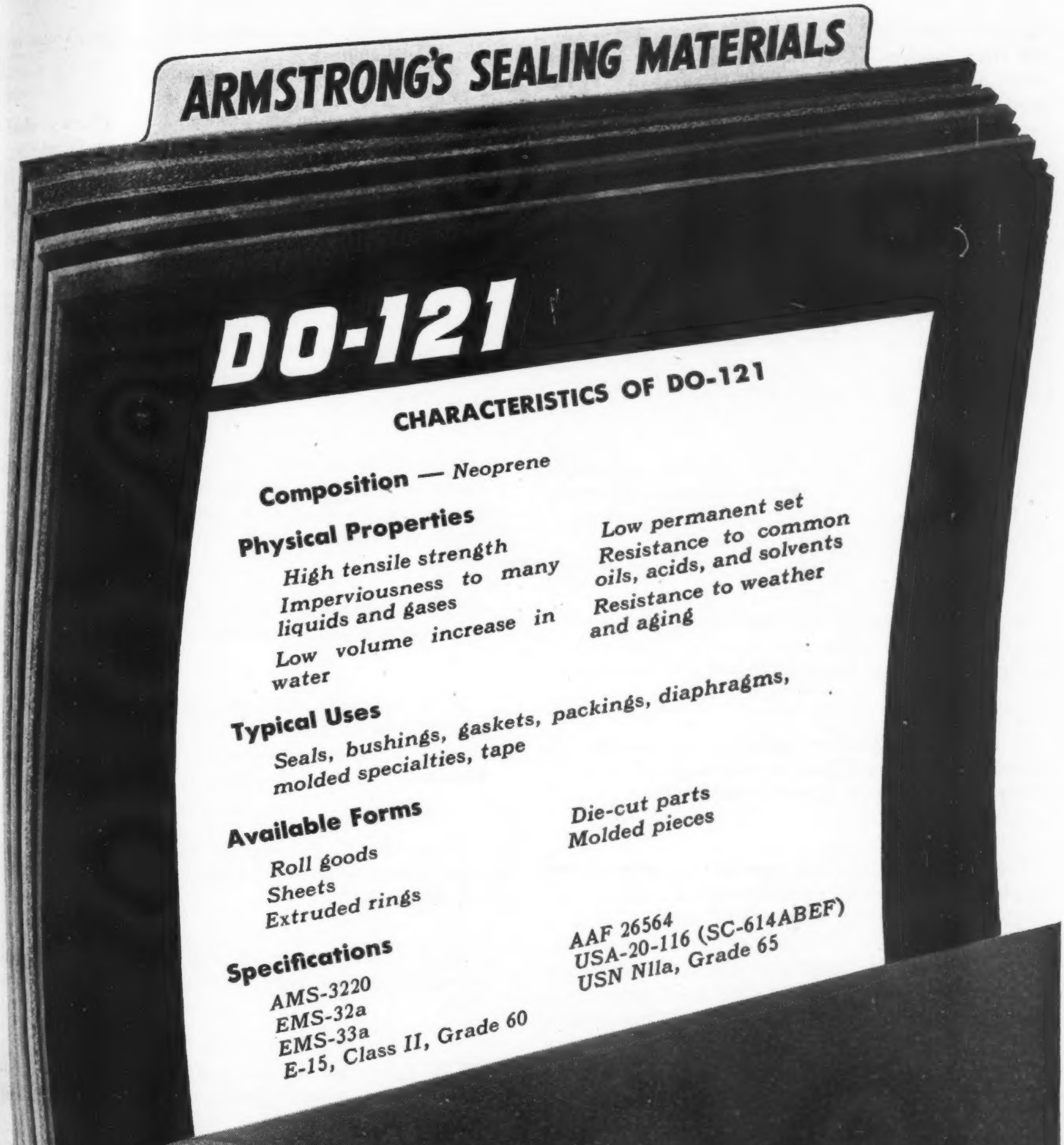
DR. V. N. KRIVOBOK has become connected with the development and research division, International Nickel Co. Inc., New York. Dr. Krivobok until recently had been chief metallurgist, Lockheed Aircraft Corp., Burbank, Calif., and formerly was professor of metallurgy at Carnegie Institute of Technology. From 1924 until 1941, he also served as associate director of research, Allegheny Ludlum Steel Corp., Brackenridge, Pa.

♦

SOREN H. MORTENSEN has recently been awarded an honorary Doctor of Engineering degree by Illinois Institute of Technology, Chicago, for "leadership in the development of alternating-current machinery". Mr. Mortensen is chief electrical engineer at Allis-Chalmers Mfg. Co., Milwaukee.

♦

C. S. BEATTIE, formerly manager of engineering, has been named vice president in charge of production and engineering, Delta-Star Electric Co. S. C. KILLIAN, development and research engineer, has been made chief



DO-121 is one of more than fifty sealing materials developed by Armstrong. For descriptions of these materials, see Sweet's File for Product Designers or write us for a copy of the free booklet, "Gaskets, Packings, and Seals." Armstrong Cork Company, Industrial Division, 5106 Arch Street, Lancaster, Pa.

ARMSTRONG'S
GASKETS · SEALS · PACKINGS

Synthetic Rubbers • Cork-and-Synthetic-Rubber Compositions* • Cork Compositions • Cork-and-Rubber Compositions • Fiber Sheet Packings • Rag Felt Papers • Natural Cork

*FORMERLY "CORPRENE"

engineer; while THOR FJELLSTEDT has been named assistant chief engineer. Other appointments are: MANFRED STENE as electrical engineer and R. A. STERNAMAN, mechanical engineer.

◆

WILLIAM DEWHIRST has been promoted from design engineer to chief engineer at Haskell-Dawes Machines Co., Philadelphia.

◆

L. E. ASKE, previously chief engineer of the Toastmaster division, McGraw Electric Co., is now chief design engineer in the development of electrical appliances for General Mills Inc., Minneapolis, Minn. A. HYDE is vice president in charge of engineering at General Mills.

◆

DR. ORA STANLEY DUFFENDACK has been made director of research for North American Philips Co., Irvington, N. Y. Dr. Duffendack had formerly been professor of physics at the University of Michigan.

◆

A. J. SCHMIDT is mechanical engineer at American Machine & Foundry Co., Brooklyn, replacing design engineer L. FERENCI who is no longer connected with the company.

◆

G. N. HANSON, product engineer in the research laboratory of the Sperry Gyroscope Co., Garden City, N. Y., has been made director of product development.

◆

NOEL URQUHART, chief engineer of Control Instrument Co., Brooklyn, is now vice president of the company.

◆

ROLLIN H. MAYER, formerly associate radio engineer in the Navy radio and sound laboratory, Los Angeles, is engineer in charge of research at Turner Co., Cedar Rapids, Ia.

◆

A. T. NEWELL has been advanced from his post of executive vice president to president of Kenyon Instrument Co., Huntington Station, N. Y.

◆

CARL T. DOMAN, engineering head, has been made first vice president of Aircooled Motors Corp., Syracuse, N. Y.

◆

MICHAEL E. and SERGE E. GLUHAREFF (brothers) have been appointed chief engineer and assistant engineering manager, respectively, at Sikorsky Aircraft division, United Aircraft Corp., Bridgeport, Conn.

◆

KINGDON KERR is special project engineer at Douglas Aircraft Co., Santa Monica, Calif., while C. S. GLASGOW is the new assistant chief engineer of the mechanical section. J. R. GOLDSTEIN, previously head of the engineering laboratories, is in charge of the company's new research laboratories.

◆

A. CARR has taken the place of R. H. FRECK as chief engineer at Fada Radio & Electric Co., Long Island City, N. Y.

◆

FRANK G. LOGAN is now manager of development at Ward Leonard Electric Co., Mt. Vernon, N. Y. Mr. Logan formerly had been chief development engineer.

◆

D. E. ANDERSON has been promoted from development engineer to chief engineer of J-B-T Instruments Inc., New Haven, Conn.

◆

A. A. GREEN, formerly with Vought Sikorsky division, United Aircraft Corp., has been made chief division engineer in charge of product engineering in the Miami division, Consolidated Vultee Aircraft Corp., Miami, Fla.

◆

R. F. ANDLER has been advanced from chief engineer to general manager of Electrol Inc., Clifton, N. J.

◆

W. E. SLABAUGH will have postwar direction of development work, manufacture and distribution of vacuum cleaners in the electric appliance division, Westinghouse Electric & Mfg. Co., Mansfield, O.

◆

NATHANIEL E. WARMAN is the new assistant to the chief engineer of Ryan Aeronautical Co., Lindbergh Field, San Diego, Calif.

◆

H. K. STEINFELD has left Baldwin Locomotive Works to become assistant chief engineer at Brunner Mfg. Co., Utica, N. Y.

◆

J. T. FERRY has become chief engineer in the tabulating machines division, Remington Rand Inc., Brooklyn, replacing KARL BRAUN.

◆

DALE ROEDER, military truck design specialist, has been appointed chief engineer at the River Rouge, Mich. plant of Ford Motor Co.

◆

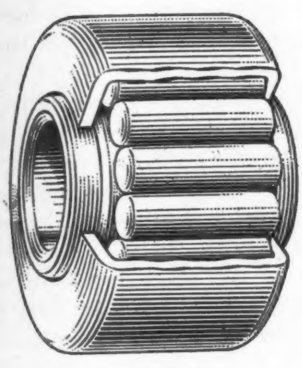
WILLIAM G. SCHNEIDER is now product development engineer of Nordberg Mfg. Co., Milwaukee.

◆

W. S. JAMES, chief engineer, Studebaker Corp., South Bend, Ind., has been elected president of the Society of Automotive Engineers.

◆

EDWARD J. PARTINGTON has been moved to the Pacific division of Bendix Aviation Corp. in North Hollywood, Calif., as development engineer.

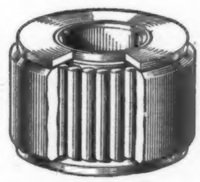


TYPE PN

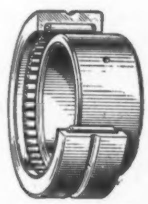
Here's Another New Needle Bearing in The Torrington Line

TYPE DC

TYPE FDT



TYPE AT



TYPE NCS

TYPE RC

THE PN TYPE NEEDLE BEARING, DESIGNED PRIMARILY FOR AIRCRAFT PULLEYS, OFFERS INTERESTING ADVANTAGES IN OTHER THAN PULLEY APPLICATIONS

•

The most recent addition to the types of Torrington Needle Bearings currently available is the PN Needle Bearing designed for aircraft pulley applications.

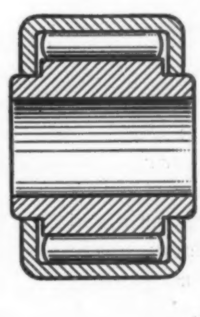
Utilizing the Needle Bearing principle of a full complement of small diameter needle rollers, this new addition to the Torrington line offers the same basic advantages as the other types: high radial load capacity, light weight, compact size, efficient lubrication, ease of installation, and, of course, gives the desired ease and "feel" of anti-friction operation.

Standard (Army and Navy Specification AN-FF-P-796) Aircraft Pulleys equipped with the PN Type Torrington Needle Bearing are currently available. They offer plane builders another opportunity to utilize the same advantages which have made Torrington Needle Bearings so widely used by the industry, particularly in aircraft control applications.

Other Applications Foreseen

The sturdy construction and simplicity of the design of the PN Type Needle

Cross-section shows detail on the PN Type Torrington Needle Bearing. Full complement of rollers eliminates danger of stress concentration. "Cup" design of outer raceway aids efficient lubrication



Bearing, as illustrated in the accompanying x-section, suggests that it will find many uses in applications other than aircraft pulleys where a compact, high capacity, low cost anti-friction unit can be employed. It is installed by a simple press-fit into the outer "housing" and the bore of the inner race fits directly over the shaft or axis.

If you are interested in either Needle Bearing equipped aircraft pulleys or in the application of the new PN Type Needle Bearing for other uses, our engineering department will gladly provide more information. Further data on the features and advantages of this and other types of Torrington Needle Bearings will be found in our Catalog No. 109 available on request. Write for your copy today.

• • •

THE TORRINGTON COMPANY
Established 1866 • Torrington, Conn. • South Bend 21, Ind.
"Makers of Needle Bearings and Needle Bearing Rollers"

New York · Boston · Philadelphia
Detroit · Cleveland · Seattle
San Francisco · Chicago · Los Angeles
Toronto · London, England

TORRINGTON
NEEDLE BEARINGS

Enveloping Worm Drives

(*Concluded from Page* 140)

nance of the tools will prevent many difficulties in the cutting, and will reduce the usually unavoidable running-in of the drive after cutting.

Drives with modified gear are started with a cutter head of the same kind. ***Fig.*** 11 shows a drive made by method 3 or 4, with about the same proportions as in *Fig.* 5. There is complete tooth contact on both sides over the full length of the worm, but only in the center plane. The actual tooth contact on this type of drive is superior to the previous one, resulting in higher power capacity for equal dimensions.

According to method 3, a basic worm is cut into a tool-steel blank which has the same shape as the final worm except for the clearance at the bottom of the gear teeth. Flutes are cut into the threads of this worm and the teeth relieved under the cutting edges, leaving only .03 to .05-inch of "land" for keeping the true profile. This hob is then used for cutting the gear so that the correct shape of tooth is copied into the gear. The gear blank may be made to any profile radius between R_{w_1} and R_{pg} minus the addendum of the tooth, *Fig.* 5. Since the profile radius of the gear, R_{pg}, is greater than the largest radius of the hob, the width of the spaces between the teeth will increase toward the sides of the gear. This condition is analogous to the increased space between the threads of a modified worm. If the proportions of the set exceed a certain range, edges between the teeth will remain after cutting, as shown at the upper right in *Fig.* 11.

Cutters Cannot Be Resharpened

Since both the worm and the gear hob are made by the same cutter head, the shape of the teeth on worm and gear will match perfectly, providing all tools are made and used with perfect accuracy. This, however, presents the great difficulty in the application of the method. A globoid hob differs from an ordinary gear hob, or from a cylindrical worm gear hob, in that every cutting tooth on the globoid hob has a different radius and a different position relative to the centerline. Since the radii of the teeth must be retained, it has so far not been considered possible to relieve the teeth of such hobs by backturning. Therefore, after the "land" under the cutting edges is removed by resharpening, the hob becomes useless. The heat treating of these hobs presents problems, too; so far no method for finish grinding of the teeth has been developed, hence the heat treating must be done without warpage and surface decarburization. Such difficulties, together with similar ones on the cutter head, make this method too expensive for practical use.

An important improvement in this respect was developed under a patented method, according to which the cutting teeth in both cutter head and hob are made narrower than the finished grooves in the blanks of gear, worm or hob, and the final width is obtained by an additional rotary feed between cutter and blank during the cutting operations. In this way any further reduction of the cutter teeth due to regrinding can be compensated by increasing this rotary feed. A worm manufactured by this method, which is utilized in the production of Cone drives, is shown in *Fig.* 12. It has, in principle, the shape of a basic worm. The outer portions of the threads, near the maximum distance (base circle radius) from the center, are relieved to prevent interlocking with the gear teeth.

Method 4 (corrected modified gear) uses the fact that only the end teeth (at the end of the threads) of the globoid hob generate the full modification of the gear teeth. If the inner teeth of a globoid hob are removed, and only the teeth with the largest radius (largest distance from the hob axis) are left, the hob will still cut a modified gear. A hob of this shape can easily be designed with inserted teeth, which eliminates many of the problems mentioned in connection with full-length hobs. Use of this hob for modifying a basic gear represents an efficient method for manufacture of globoid drives, *Fig.* 13.

Finished by Lapping

So far all globoid worm drives have been finished by lapping or running-in of worm and gear in the position of final application. This means that a certain amount of profiling of the teeth is done by a generating process, equal to a combination of the outlined methods. The greater the amount of material left after the cutting and removed by running-in, the closer the approach to the theoretically correct tooth form and the better the tooth contact and therefore the power capacity. With a well-designed and well-performed manufacturing setup, not more than .005-inch should be needed for running-in, and if the drive is designed for easy manufacturing from the start, incorporating hunting-tooth ratio and adjustable center distance between worm and gear, only lapping with thin oil (without abrasive) may be sufficient. This is especially important for drives intended for continuous high-speed operation where the traces of abrasive always remaining in the metal of the teeth would increase the wear in operation. On the other hand, in some cases manufacturers prefer to save on tool cost by leaving a total of .03-inch for running-in, which is then done with sharp abrasive compound for 70 hours and more.

Providing for Accurate Location

For the accurate location of worm and gear, a basic necessity for every globoid drive, provision must be made in the original design. All bearings should be the anti-friction type and, if tapered roller bearings are used, correct locations of worm and gear should be adjustable to remove end play. Both worm and gear should be adjustable axially by shims. Adjustability of the center distance may seem difficult, but will prove highly advantageous in some applications.

Up to the present, only a few manufacturers have developed facilities for production of globoid gears, although the advantages of this type of drive are well acknowledged. As previously mentioned, one reason is the difficulty of manufacture. Another is the difficult coordination of design and manufacture, since most globoid drives now in use are made by specialized manufacturers who do not originate the design of the whole machine.

The Monitor THERMALOAD V Solenoid Motor Starter

The BIG difference between the Thermaload V and *ordinary* motor starters lies in Monitor's exclusive Compensated Overload Relay. This unique relay—not found on other motor starters—eliminates the hazards of unjustified shutdowns in hot locations, guarantees protection against overload in cold locations. Obviously, this means that your motors are constantly guarded against damage . . . that your production schedules can be maintained without unnecessary interference.

Other important advantages of the Thermaload V are (1) interchangeable coils for different voltages (2) double break silver-to-silver contacts (3) tamper-proof reset button (4) accessibility of parts for easy maintenance (5) built-in quality.

Get the facts on Monitor's Thermaload V now! Remember, it's the product of a company with over 50 years' experience in the manufacture and design of quality motor controls. See your nearest Monitor field engineer—or write direct for descriptive Catalog 6300.

How Monitor's Compensated Relay Works

This unique, compensated overload relay consists of two bi-metal, thermally-activated helices. When activated by ambient temperature, they oppose and nullify each other . . . thus no tripping action is imparted. HOWEVER—one helix is surrounded by a "heater coil" through which flows motor current. When motor current becomes excessive due to overload, a proportional temperature rise occurs in the heater coil . . . is impressed upon the ONE helix . . . producing the motion necessary to open the tripping contact and disconnect the motor from the line. Yes, this compensated overload relay is a Monitor "exclusive."

WE CAN SUPPLY YOU

with the Thermaload V under existing priority regulations from our present stock. Available for motor ratings up to 3 H.P., 110 Volts, A.C. and up to 7.5 H.P., 550 Volts, A.C. Furnished also in combination units . . . choice of general purpose, dust-tight or water-tight enclosure. Mounting suitable for front-of-board or back-of-board wiring.

Monitor — The Original — Just Press a Button System

The Monitor Controller Company

GAY, LOMBARD & FREDERICK STS. BALTIMORE-2, MARYLAND

CANADIAN AFFILIATE • CANADIAN CONTROLLERS LTD. • TORONTO, ONTARIO, CANADA

ASSETS to a BOOKCASE

Twentieth Century Engineering

By C. H. S. Tupholme, published by Philosophical Library, New York; 201 pages, 5½ by 8⅞ inches, clothbound; available through MACHINE DESIGN, *$3.00 postpaid.*

One of the seemingly unfortunate aspects of current engineering procedure is the confined scope of the individual's knowledge due to specialization. There are times when many of us feel that we would like to know a great deal more about the intricacies behind phases of engineering outside our immediate sphere. Since there simply isn't time for any man to become expert in all things, it is necessary to strike a compromise and be satisfied with an intimate understanding of our own work plus only a rather general knowledge of the other branches of engineering.

Most likely the key to what such general knowledge should consist of may be found in the relationship which exists between all phases of engineering. Some are allied more closely than others but in all cases a definite link exists. Thus it would seem that the engineer should be on speaking terms with the broad basic principles underlying all scientific endeavor and should know also something of their present-day applications.

This is not a technical book in the strict sense of the word. It contains no formulas for calculating stress and strain, power requirements, heat losses, or the like, but confines itself to presenting an overall picture of the outstanding engineering devices and processes which have been developed in recent years. It is a book to read at leisure, for while it is enlightening it is not profound. Enhanced by an adequate number of drawings and photographs, it discusses mechanical power, engineering workshop processes, air-conditioning and refrigeration, chemical and metallurgical engineering, electrical engineering, traction, marine engineering, aircraft and physics.

□ □ □

Conveyors and Related Equipment

By Wilbur G. Hudson; published by John Wiley & Sons Inc., New York; 341 pages, 5-7/16 by 8-5/16 inches, clothbound; available through MACHINE DESIGN, *$5.00 postpaid.*

For the chief engineer and designer who wants to evaluate methods of moving bulk materials for processing and loading this book has much to offer. Its aim is to present a broad picture of the more prevalently employed types of conveyors and allied equipment such as hoists, tramways, crushers, hammermills, pulverizers, screens, feeders, etc. Details of the design of component parts; chains, bearings, shafting, gearing and the like are accorded but little attention since they usually are furnished as complete purchased items.

There are many considerations which must carefully be taken into account when conveying equipment is being specified. Equipment that is suited ideally for handling coal could not be expected to handle a material such as cement properly. Also from the material standpoint, substances which throw off dust—especially explosive dust—require special kinds of equipment. Other factors are plant layout, capacities and weights, clearances required, and material corrosion tendencies. All of these points are discussed in comprehensive fashion.

Considerable information of a design nature is included on capacities, speeds, losses and power requirements; estimated weights and costs of equipment are given in a number of instances and the many tables of data should be quite useful. It is a well-prepared, authoritative treatise and is amply illustrated with charts, drawings and photographs.

□ □ □

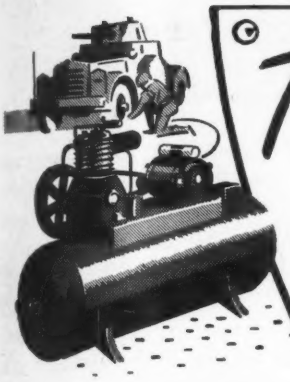
Materials and Processes

By James F. Young, General Electric company; published by John Wiley & Sons, Inc., New York; 628 pages, 5⅜ by 8-5/16 inches, clothbound; available through MACHINE DESIGN, *$5.00 postpaid.*

There is always room for another good book which gives the machine designer ready reference to information on engineering materials and the processes of their fabrication into parts. As Mr. Young points out in his preface, much of the available information on metallic materials is presented largely from the metallurgist's viewpoint, and too often information on manufacturing methods tells how to effect the processes and how to operate the equipment used. What the designer wants is the kind of data he can put to use "on the job". He wants to know what the various materials will do for him and, insofar as processes are concerned, he seeks the kind of data which prepares him to design more competently the parts to be produced by means of the various methods.

The preparation of a book of this type is an ambitious undertaking, for it necessarily must cover a large number of subjects. However, by wisely drawing on the knowledge and experience of men who are experts in their given fields, the author has succeeded in presenting an overall picture which the design engineer should find of considerable value.

In the section dealing with materials, due consideration

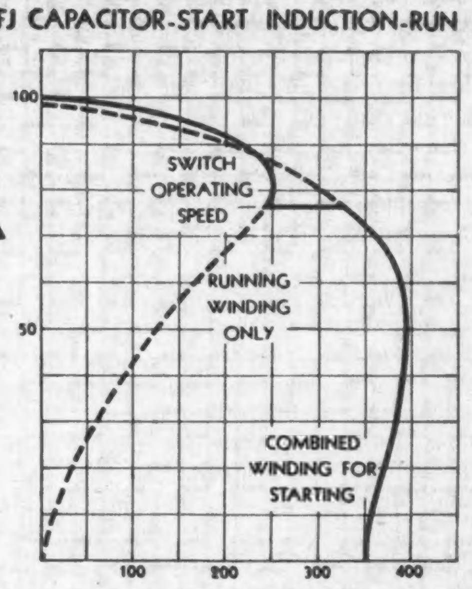


Torque Talks

ON MOTORS FOR WAR AND POST-WAR NEEDS

SINGLE-PHASE MOTORS THAT DELIVER

A starting wallop!



For heavy-duty jobs requiring quiet operation ... high starting and pull-in torque ... and low starting current, this capacitor-start motor is ideal.

The Type FJ Capacitor Start General-Purpose Motor has an efficiency and power factor among the highest of any fractional horsepower, single-phase motors.

Starting torque of 300 to 450% ... with 225-300% breakdown torque, with low starting current ... ideal for all heavy-duty applications.

Type FJ motors are champs when it comes to slugging it out on such two-fisted jobs as compressors, pumps, machine tools, refrigerators, air-conditioners and stokers.

ASK FOR APPLICATION HELP

Small motors have gone to war ... some on varied applications of peacetime products ... many others on specialized war applications. For condensed information on Westinghouse small motors, the Westinghouse Small Motor Selector (Booklet 3075-A) summarizes the data presented in these "Torque Talks". Write for your copy of this helpful aid to proper motor selection. Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pennsylvania. J-03198

PICK THIS MOTOR

TYPE FJ CAPACITOR START GENERAL PURPOSE MOTOR

- For heavy-duty service
- For quiet operation
- For high starting torque
- For low starting current

PHASE—Single CYCLES—60, 50, 25
HORSEPOWER—1/15 to 3/4
VOLTS—115 or 230 for 1/4 hp 4 pole and smaller: larger sizes are 115/230 dual voltage
SPEEDS—(approximate full load rpm)
60 cycles—3450, 1725, 1140, 860
50 cycles—2850, 1425, 960
25 cycles—1425

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SMALL MOTORS

is accorded the designer's responsibility to use materials properly, i.e., to so shape and proportion his parts as to utilize fully the inherent strength of the materials, and to analyze carefully the nature, direction and magnitude of the loading involved. Brief but comprehensive, the discussion on steels includes data about the effects of alloying elements on hardenability, Jominy tests, heat treating, relation of design to heat treatment and heat-treatment specifications. Corrosion of metals and their electrical, magnetic and chemical properties are dealt with at length.

Most likely the chapters which will have the greatest appeal to designers are those dealing with the many fabricating processes, for throughout these chapters emphasis is placed on the influence which the processes exert on the actual design of the parts produced. All of the prominent processes are elucidated thoroughly including sand, plaster and metal-mold casting; forging, press working, spinning, welding, and all kinds of machining and grinding. The chapters on powder metallurgy and induction heating are particularly timely as are the data on recent developments in welding and metallizing.

□ □ □

Control of Electric Motors

By Paisley B. Harwood, manager of engineering, Cutler-Hammer Inc. and Fellow, American Institute of Electrical Engineers; second edition; published by John Wiley & Sons Inc., New York; 479 pages, 5½ by 8-5/16 inches, clothbound; available through MACHINE DESIGN, *$5.00 postpaid.*

Outside of the transportation field, by far the majority of machines are powered by electric motors. In mechanisms which utilize hydraulics, the pump almost invariably is driven by an electric motor. If pneumatics is employed, the compressor is similarly driven, and where drives and transmissions are purely mechanical, again the electrical rotating power source predominates.

With so many different kinds of motors and motor controllers available to the machine designer, he often finds the task of selecting the right type for a given application somewhat perplexing. While it is true that motor and controller manufacturers generally have well qualified field engineers whose specific job it is to aid the designer in his selection, a comprehensive knowledge of the fundamentals involved can be of considerable help.

This book gives the designer what he should know to specify motors and their controls in a competent manner. For example, requirements of the machine to be driven being predominant factors, a list of these starting, stopping, reversing, running, speed control and safety feature requirements is supplied in handy reference form. Again, the influences exerted by power supply and methods of machine operation are discussed.

In this second edition, chapters on synchronous-motor control and variable-voltage control have been added as well as many new tables giving the ratings of motors and controllers. With so much present interest centered on electronics, the section devoted to this phase of control is particularly significant.

Applying Valves

(*Continued from Page* 122)

Obviously the table-locking plunger must be disengaged before the table can be turned. This is accomplished during the first few degrees of the cylindrical cam's revolution when the dwell portion of the cam path is engaged with one of the table rollers. While the cylindrical cam is turning through these few degrees of dwell, the cam for valve 2 is turning in step with it and as soon as it has turned far enough to permit the spool of valve 2 to snap into its "roller out" position, a path exists from port *Q* to *EX* for the fluid being forced out of chamber *CC* in unit 17. Thus, the locking plunger disengages before the work table turns.

Exhaust Path Automatically Provided

Since pressure now flows through ports *P* and *R* of valve 2, it will enter the right-hand piloting chamber of four-way valve 3 through port *W*, moving the valve spool to the left and opening a path through ports S and C for pressure which will come from port *BB* of 17 when the locking plunger again is engaged.

After the work table has been indexed through one-sixth of a turn, the cam for valve 2 pushes its spool into the position permitting pressure passage through its ports *P* and *Q* to port *CC* of 17, moving the locking plunger into engagement. Pressure then can pass through port *BB* of 17, on through ports S and *C* of valve 3 to pilot connection *X* of valve 5. This moves the spool of valve 5 to the left and, were it not for the fact that the cam of valve 1 has just pushed its spool into the "up" position, the rams would start down again. However, with the spool of valve 1 in the position shown, and valve 13 set in its "stop" position, pressure passes from port *RR* of valve 13, through ports *F* and *G* of valve 1 and on to pilot the spool of valve 4 to its "right" position. This action valves the pressurized fluid from the pump back to the exhaust line via port *L*. Thus, with no fluid being fed to either the rams or the fluid motor through valve 5, the press shuts down. All fluid from the pump by-passes back to the reservoir.

The Problem of Load Holding

There are many instances where it is necessary not only to move a load by means of hydraulic power, but also to hold the load at any given position for long periods of time. To effect such holding by means of a hand-operated shutoff valve presents no problems to speak of at all. However, accomplishing load-holding *automatically* can be quite another matter.

To demonstrate what is involved, attention is called to the simple circuit shown in *Fig* 5. The loaded piston, having been moved to the position shown, must be held there positively for a considerable interval. Thus, with the four-way valve spool in the position indicated, all oil from the pump will be passed through the valve back to the reservoir or tank and, since both lines leading

(*Continued on Page* 196)


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ST. LOUIS · SAN FRANCISCO · LOS ANGELES · DETROIT

(*Continued from Page* 190)

to the power cylinder are blocked, the oil in them will be at rest. However, the oil in line *A*, since it supports the loaded piston, will be under pressure. Because there must be clearance between the spool and the cylinder bore of the four-way valve, the pressurized oil from line *A* will leak slowly past the spool and back to the the tank, permitting the loaded piston to drift slowly until it reaches the end of its cylinder.

Special Valve Unit Solves Leakage Problem

By creating a valve unit which combines a four-way valve with a special two-way check valve, Gar Wood Industries Inc. has solved this leakage problem. A cutaway view of the valve unit is shown in *Fig.* 6. *Fig.* 7 *a, b* and *c* indicate how oil flows through the unit during the "power-up", "hold" and "power-down" cycles, respectively.

Located at the right of the four-way valve, the two-way check valve comprises two moving parts, a tappet and a double-flanged spool, both of which are spring loaded. In operation, when extending the powered piston, *Fig.* 7*a*, the pressurized oil flows from port *B*, through the four-way valve and into the chamber between the tappet and spool of the check valve. Its first action inside the check valve is to react on the spool, the flange of which has a larger area exposed to the pressurized oil than does the tappet. Thus, the spool is pushed up to its stop, providing a return path for oil from the power cylinder via port *C* to tank. The pressure then acts on the tappet, pushing it downward and opening the line to the cylinder via port *D*.

When the piston being powered has been moved the desired distance and it is required to hold it there under load, the four-way valve spool is shifted manually to the position shown in *Fig* 7*b*. Now the oil in the check valve and in both lines leading from it via ports *C* and *D* to the power cylinder is at rest. Static pressure exists above and below the check-valve tappet, permitting its spring to push it up against its seat and thus effect a positive fluid seal.

With pressure no longer existing between the check-valve tappet and spool, the spool will be actuated by its spring and the oil it displaces seeps past its lower flange to the space between the lower and upper flanges.

To start the "power-down" cycle, the four-way valve is shifted to the position shown in *Fig.* 7*c*. Pressurized oil from the pump acts against the upper flange of the check-valve spool, causing it and the tappet to move downward. It will be seen that this arrangement always allows a relief path for oil from the power cylinder before permitting oil under pressure to enter the power cylinder at its opposite end.

Hydraulic Fuse Protects System

Another interesting combination unit, this one incorporating the functions of a check valve and metering dash pot, was patented by Simmonds Aerocessories Inc. a short time ago. Known as a "hydraulic fuse", *Fig.* 9,

Got a Tough Job

FOR A FRACTIONAL H.P. MOTOR?

S P E C I F I C A T I O N S

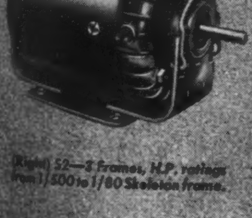
Frame	Rated H.P.	No Load RPM	Full Load RPM	Length	Diameter	Mounting*	Ask for Bulletin No.
4A	1/20 -1/15	1750	1475	$5\frac{5}{8}''$	$4\frac{7}{16}''$	R,B,Res.	8A
6J	1/100-1/25	1750	1550	$5\frac{1}{4}''$	$3\frac{15}{16}''$	R,B,Res.	6J
6H	1/100-1/25	1750	1550	$3\frac{3}{4}''$	$3\frac{13}{16}''$	R,B,Res.	6H
6G	1/100-1/25	1750	1550	$3\frac{3}{4}''$	$3\frac{13}{32}''$	R,B,Res.	6G
6A	1/225-1/25	1750	1550	$3\frac{3}{8}''$	$3\frac{5}{16}''$	R,B,Res.	6A-1
E2	1/125-1/80	3400	2500	$3\frac{7}{8}''$	$3\frac{5}{16}''$	R,B	A.K.
S2	1/125-1/80	3400	2500	$3\frac{3}{8}''$	$3\frac{1}{4}''$		A.K.
E3	1/175-1/125	3400	2500	$2\frac{3}{4}''$	$3\frac{5}{16}''$	R,B	A.K.
S3	1/175-1/125	3400	2500	$2\frac{5}{8}''$	$3\frac{1}{4}''$		A.K.
S1	1/500-1/175	3400	2500	$2\frac{5}{16}''$	$3\frac{1}{4}''$		A.K.

*R Plain Round — B with Base — Res Resilient Mounting

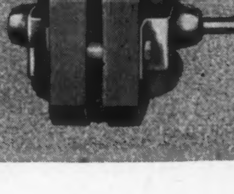
Here's a Guide to Help You Select Your "Job-Rated" Pilot F.H.P. Motors

WHETHER it's a product already in production or a new "post-war" product now in the early stages of planning, it will pay you to look into the standard line of PILOT Fractional H.P. MOTORS. Smooth . . . quiet-running . . . efficient . . . these "little giants of power" are available in "job-rated" types to meet practically every power drive requirement. Study the above chart . . . then write for Bulletins pertaining to the motor or motors which meet your specifications.

F. A. SMITH MFG. CO. INC., 401 DAVIS ST., ROCHESTER 5, N. Y.



(Left) 6J—2 Frames, H.P. ratings from 1/100 to 1/25 in either plain round or Base or Resilient Mounting.



(Right) S2—3 Frames, H.P. ratings from 1/500 to 1/80 Skeleton frame.

(Above) E2—2 Frames, H.P. ratings from 1/175 to 1/80 in either plain round or with Base mounting.

Pilot *Fractional H.P.* **MOTORS**

its function is to protect against loss of fluid in a hydra[ulic] system when a line is ruptured. Movement of the check[ing] ball to and from its seat is determined by the ra[te] at which the fluid bleeds in or out of the dash pot orifi[ce]. Thus, with flow existing in the direction indicated, aft[er] a predetermined amount of fluid has passed throu[gh] the unit, the ball will seat and by so doing effective[ly] check further flow.

Typical Circuit Uses Two Fuses

A simple application of two of these units is show[n] schematically in *Fig.* 10 where they are used to guar[d] against fluid loss in the event either of the lines betwee[n] the selector valve and cylinder are ruptured. The da[sh] pot orifices are of such size as to permit passage of a[n] amount of fluid slightly in excess of that required to ene[r]gize the cylinder piston through its entire stroke an[d] should line rupture occur between the fuses and th[e] cylinder, flow will be checked after this predetermine[d] quantity of fluid has been permitted to leak out.

To obtain maximum protection through the use o[f] such a unit requires that it be installed in the line a[s] close as possible to the selector valve. These units ar[e] suitable for use only in hydraulic circuits having alte[r]nating or two-direction flow and should not be employe[d] in a continuous flow circuit because, after passing th[e] prescribed quantity of fluid, they would shut off and bloc[k] the system.

Tests indicate successful operation regardless of varia[]tions in either oil viscosity or rate of flow and also tha[t] the units are not affected by back pressure or surges. It is claimed the units will function properly over [a] temperature range of from minus 65 to plus 140 degree[s] Fahr. and under laboratory conditions simulating from 4 to 10 *g*. The number of "fuses" needed in any lin[e] is determined by the number of components, the vulner[]ability of the line to damage and the practicability o[f] installation.

Automatic Systems Require Careful Planning

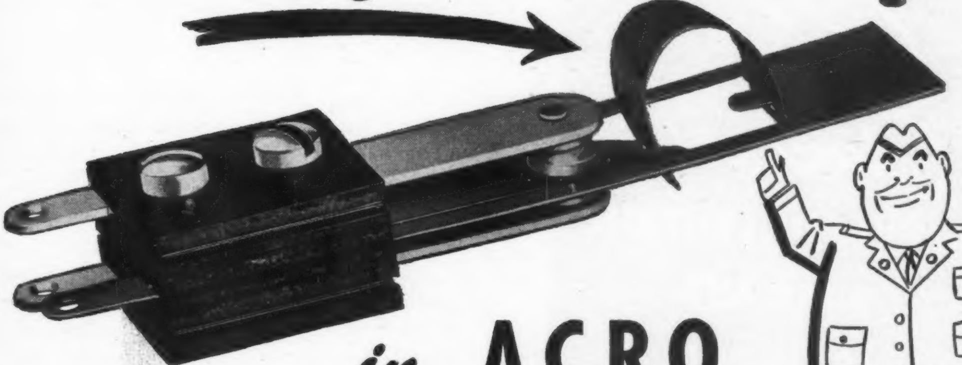
While simple types of hydraulic systems require onl[y] the briefest kind of planning, the complex, interlockin[g] types, featuring foolproof automaticity, often can be quit[e] puzzling. Their development requires first, that th[e] designer be equipped with a thorough understanding o[f] what all available types of pumps, valves and conversio[n] units can do. Thus armed, he can proceed on a step by step basis to rough out schematically the simples[t] and most direct circuit to fit the job's specific require[]ments. In general, sequencing of operations through th[e] use of the various types of direction-control (selector) valves is planned first, after which check valves, restric[]tors, shutoffs, etc., can be added as needed by the par[]ticular application.

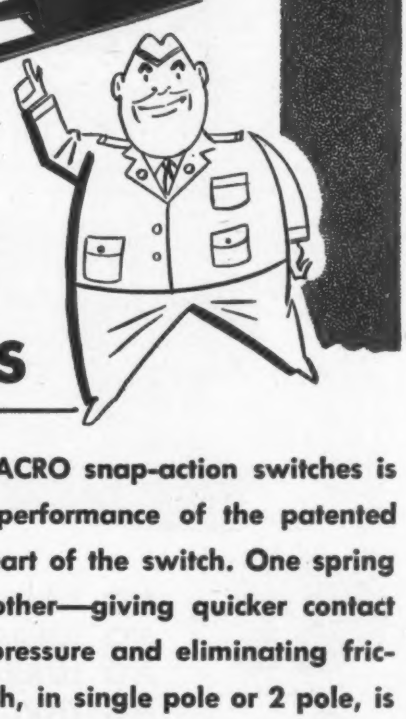
CORRECTION: In the article, "Electric Auxiliary Drives for Aircraft" beginning on Page 159 of the Apr[il] issue, the author, Richard M. Mock, was incorrectly give[n] the title of president of Lear Avia Inc. Instead he is vice-president of that company. We regret this error oc[]curred.—Ed.

WATCH!

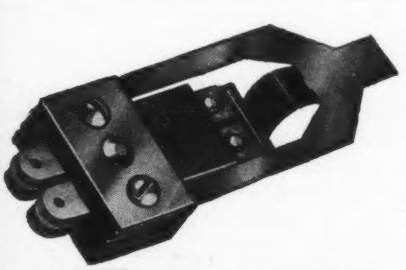
the Performance of the

Rolling Spring





in ACRO
SNAP-ACTION SWITCHES



Two Pole Open Blade Switch With Independent Circuits Controlled by One Actuation.

Acro Midget Switch Designed with Actuating Pin Below. 10 Amps at 115 Volts A. C. 1½" Long.

Rising preference for ACRO snap-action switches is due to the amazing performance of the patented Rolling Spring—the heart of the switch. One spring actually triggers the other—giving quicker contact break, firmer contact pressure and eliminating friction. Open blade switch, in single pole or 2 pole, is rated 15 amps on 115 volts A. C., or 7½ amps on 230 volts. Made normally open, normally closed or double throw. Approximately 3" long and ½" to 1" widths. Approved by the U. S. Army Air Forces and used on all types of war equipment. If your future production is not yet planned for ACRO switches, write us details of your particular needs now.

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BUSINESS AND SALES BRIEF

FORMERLY assistant to the manager of the appara publicity divisions, Willard V. Merrihue has been appointed manager of the advertising and sales promotion divisions, apparatus department, General Electric Co. At th same time he was made a member of the apparatus sales committee.

◆

Among personnel changes made by Allis-Chalmers Mf Co. is the election of William C. Johnson as vice preside Formerly Mr. Johnson had been general sales manager.

◆

Celebration of its twenty-fifth anniversary was announce recently by Chicago Molded Products Corp. In 1919 si brothers of the Bachner family founded the organizatio which was known as Plymouth Mfg. Co.

◆

According to a recent announcement, James Tate has bee named director of marketing, The Dumore Co., Racine, Wis. and will be responsible for the development and sale of fractional horsepower motors and precision tools offered by th company.

◆

Under the management of Frank D. Ratcliffe, district manager, oil industry sales, a new office has been opened at 133 Hunt building, Tulsa, Okla., by Fairbanks, Morse & Co.

◆

Worthington Pump & Machinery Corp., Harrison, N. J., has announced the appointment of Walter D. Smith as a commercial vice president. Mr. Smith, who had been manager of the Tulsa district office for the past four years, will supervise business of the corporation in the Southwest.

◆

Succeeding the late John C. Brooks is Felix N. Williams as general manager, Plastics division, Monsanto Chemical Co., St. Louis. Mr. Williams will make his headquarters at Springfield, Mass.

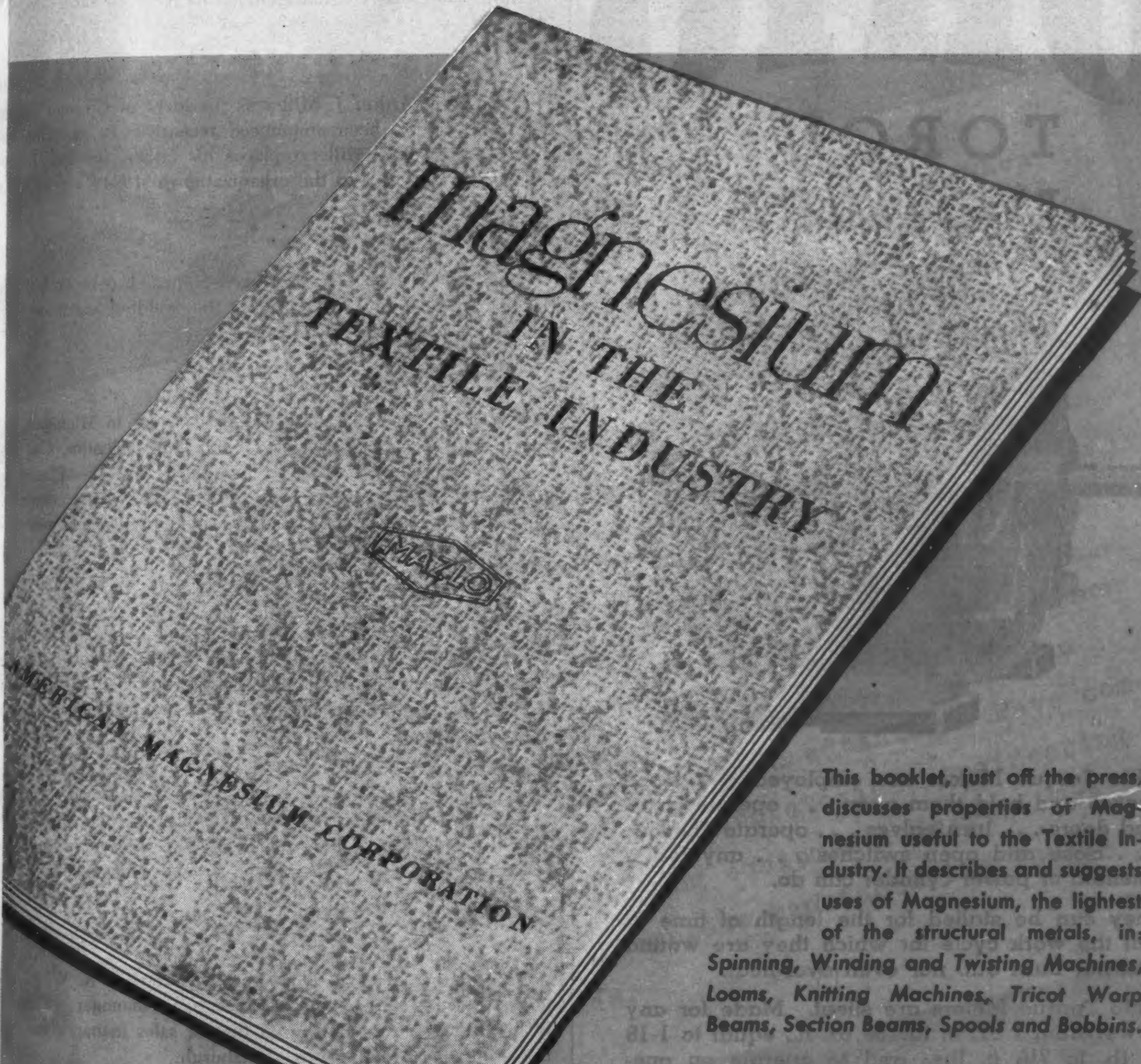
◆

Located in the Citizens State Bank building, a new branch office in Houston, Texas, has been opened by The Bristol Co. With former resident sales engineer D. D. Ault in charge, the new office will serve Louisiana and Texas with the exceptio of the Panhandle section.

◆

Transfer of vice president Harold B. Ressler from the New York plant to executive offices in Chicago has been announced by Joseph T. Ryerson & Son Inc. Mr. Ressler will be in general charge of sales in all territories. Also announced is the

Textile Machine Designers and Mill Men will find this *new booklet* very helpful



This booklet, just off the press, discusses properties of Magnesium useful to the Textile Industry. It describes and suggests uses of Magnesium, the lightest of the structural metals, in: ***Spinning, Winding and Twisting Machines, Looms, Knitting Machines, Tricot Warp Beams, Section Beams, Spools and Bobbins.***

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appointment of Thomas Z. Hayward as assistant general manager of sales. With the company for twenty-seven years, Mr. Hayward had been in charge of tubing sales and priorities.

♦

Particularly known for development work in applying gas-air combustion to automatic flame-hardening and flame-annealing, The Selas Co. has changed its name to Selas Corp. of America.

♦

Election of Arthur J. Miller as president of Chicago Wheel & Mfg. Co. has been announced recently. In assuming his new position, Mr. Miller replaces his father, the late Henry E. Miller, who formed the organization in 1894.

♦

Pacific Metals Co. Ltd. has been named distributor in California, Nevada, and Arizona for the welding equipment of A. O. Smith Corp., Milwaukee.

♦

In order to handle sales and service work in Michigan, Indiana and Toledo territory, Climax Molybdenum Co. has opened offices at 624 Fisher building, Detroit. Placed in charge of the office is V. A. Crosby who has been connected with the company for ten years as metallurgical engineer and sales representative.

♦

Addition of C. R. W. Thomas to the technical staff of sales and service engineers has been announced by the industrial division of Standard Varnish Works, New York. Sales and service activities in the Baltimore territory will be in charge of Mr. Thomas.

♦

Recently announced was the opening of a new office at 125 Circle Tower, Indianapolis, by Revere Copper & Brass Inc., New York. P. H. Anderson has been placed in charge.

♦

According to a recent announcement, Herbert A. White has joined Smeeth-Harwood Co., Chicago, as manager. Formerly he had served as Pittsburgh district sales manager for National Bearing Metals Corp., Pittsburgh.

♦

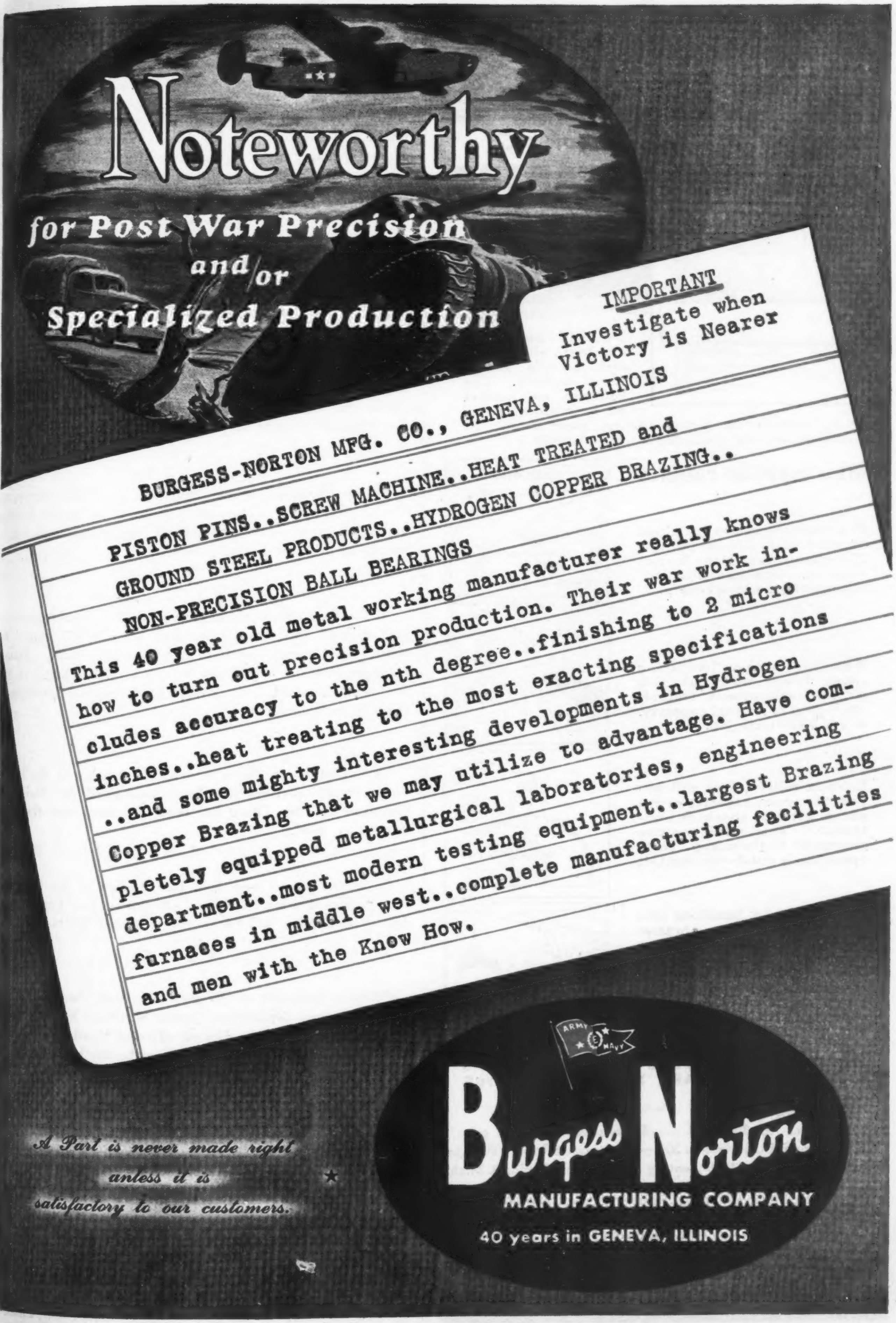
With offices at 134 Marietta street, G. E. Hunt has been appointed acting manager of the Atlanta territory of Cutler-Hammer Inc., Milwaukee. Mr. Hunt has been connected with the company since 1920 and most recently served as manager of the Indianapolis office.

♦

Offices of the newly affiliated Accurate Engineering division, Johnson Fare Box Co., will be at 4300 North California avenue, Chicago 18.

♦

Another new office for Link-Belt Co.—located at South 151 Lincoln street, Spokane, Wash.—will handle sales from the territories of eastern Washington, northern Idaho and a west-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PISTON PINS..SCREW MACHINE..HEAT TREATED and
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NON-PRECISION BALL BEARINGS
This 40 year old metal working manufacturer really knows how to turn out precision production. Their war work includes accuracy to the nth degree..finishing to 2 micro inches..heat treating to the most exacting specifications ..and some mighty interesting developments in Hydrogen Copper Brazing that we may utilize to advantage. Have completely equipped metallurgical laboratories, engineering department..most modern testing equipment..largest Brazing furnaces in middle west..complete manufacturing facilities and men with the Know How.
ARMY E NAVY
Burgess Norton
MANUFACTURING COMPANY
40 years in GENEVA, ILLINOIS
A Part is never made right unless it is satisfactory to our customers.

ern portion of Montana. Homer A. Garland, who has been connected with the company since 1922, will be in charge of this office.

♦

Connected with the company for over thirty years, A. F. Rucks has succeeded the late C. D. Waters as president and general manager of C. J. Tagliabue Mfg. Co., Brooklyn, manufacturer of indicating, recording and controlling instruments.

♦

Advancement of Henry H. Ziesing from Philadelphia sales manager to vice president in charge of sales has been announced by Midvale Co. Mr. Ziesing has been associated with the company since 1916.

♦

Succeeding E. B. Treidler who resigned recently is E. H. Mintie as direct representative and field engineer for the California and Arizona territories of Air-Maze Corp., Cleveland. Mr. Mintie will make his headquarters in Los Angeles.

♦

Change of name has been announced by Waterbury Button Co. of Waterbury, Conn., manufacturers of plastic molding and small metal wares. Henceforth, the organization will be known as Waterbury Companies Inc.

♦

New branch office quarters at 687 Boylston street, Boston 6, and at 1505 Broadway, Cleveland, have been occupied recently by General Controls Co., Glendale, Calif. Branch manager William Marsh has been placed in charge of the Boston office while L. E. Wetzel has been made manager of the Cleveland branch.

♦

Naming of W. R. Dixon as assistant manager of the Plastic Engineering division has been announced by The Dow Chemical Co. Mr. Dixon has been associated with the company since 1936.

♦

Expansion into a new field has resulted in the formation of a plastics division by Wayne Oil Burner Co., Fort Wayne, Ind. The division will be known as Wayne Plastic Products.

♦

Formerly manager of the petroleum and chemical section of the industrial department, Quincy M. Crater has been made assistant manager of the Detroit office of Westinghouse Electric & Mfg. Co. Mr. Crater will make his headquarters at 5757 Trumbull avenue, Detroit.

♦

With district manager C. N. Calkins remaining in charge, the New York offices of Allen-Bradley Co., Milwaukee, have been moved to 155 East Forty-fourth street.

♦

Moving of the recently established Chicago district office to Tribune Tower, 435 North Michigan avenue, has been announced by Vinco Corp., Detroit. This office, in charge of Fred G. Roberts as resident engineer, serves the Illinois,

Indiana, Wisconsin, Missouri and Western Michigan territory. The company's activities include design and development engineering as well as the manufacture of gages and precision machinery.

♦

For ten years in the Detroit sales office, Davis C. Green has been named St. Louis representative of Haskelite Mfg. Corp. He will be replaced in the Detroit office by Robert Burkhead.

♦

Addition of another new building to its present plant facilities in Chicago has been announced by Felt Products Mfg. Co.

♦

Controller since 1939, Charles L. Turner has been made vice president in charge of sales, Buffalo Bolt Co., North Tonawanda, N. Y.

♦

Formation of a new MetaLastic division has been announced by Cook Electric Co. Assistance in specialized bellows applications will be made available.

♦

Assistant general manager for the past year, Wallace Johnson has been named general sales manager for the Pomona Pump division of Joshua Hendy Iron Works, Sunnyvale, Calif.

♦

A new engineering service for manufacturers will be made available with the opening of offices at 649 Hilltop road, Erie, Pa., by H. G. Mueller & Associates, Pittsburgh.

♦

Joining of Bert E. Brashares as steel casting sales engineer has been announced by the Product division of Jones & Laughlin Steel Corp. Formerly he had been associated with Commercial Steel Castings Co., Marion, O., as sales manager.

MEETINGS AND EXPOSITIONS

June 19-22—
American Society of Mechanical Engineers. Semiannual meeting to be held at Hotel William Penn, Pittsburgh. C. E. Davies, 29 West Thirty-ninth street, New York, is secretary.

June 26-30—
American Institute of Electrical Engineers. Summer technical meeting to be held at Jefferson hotel, St. Louis. H. H. Henline, 33 West Thirty-ninth street, New York is national secretary.

June 26-30—
American Society for Testing Materials. Forty-seventh annual meeting to be held at Waldorf-Astoria hotel, New York. Robert J. Painter, 260 South Broad street, Philadelphia 2, is assistant to the secretary.

June 28-29—
Society of Automotive Engineers. National transportation and maintenance meeting to be held at Bellevue-Stratford hotel, Philadelphia. John A. C. Warner, 29 West Thirty-ninth street, New York, is secretary and general manager.